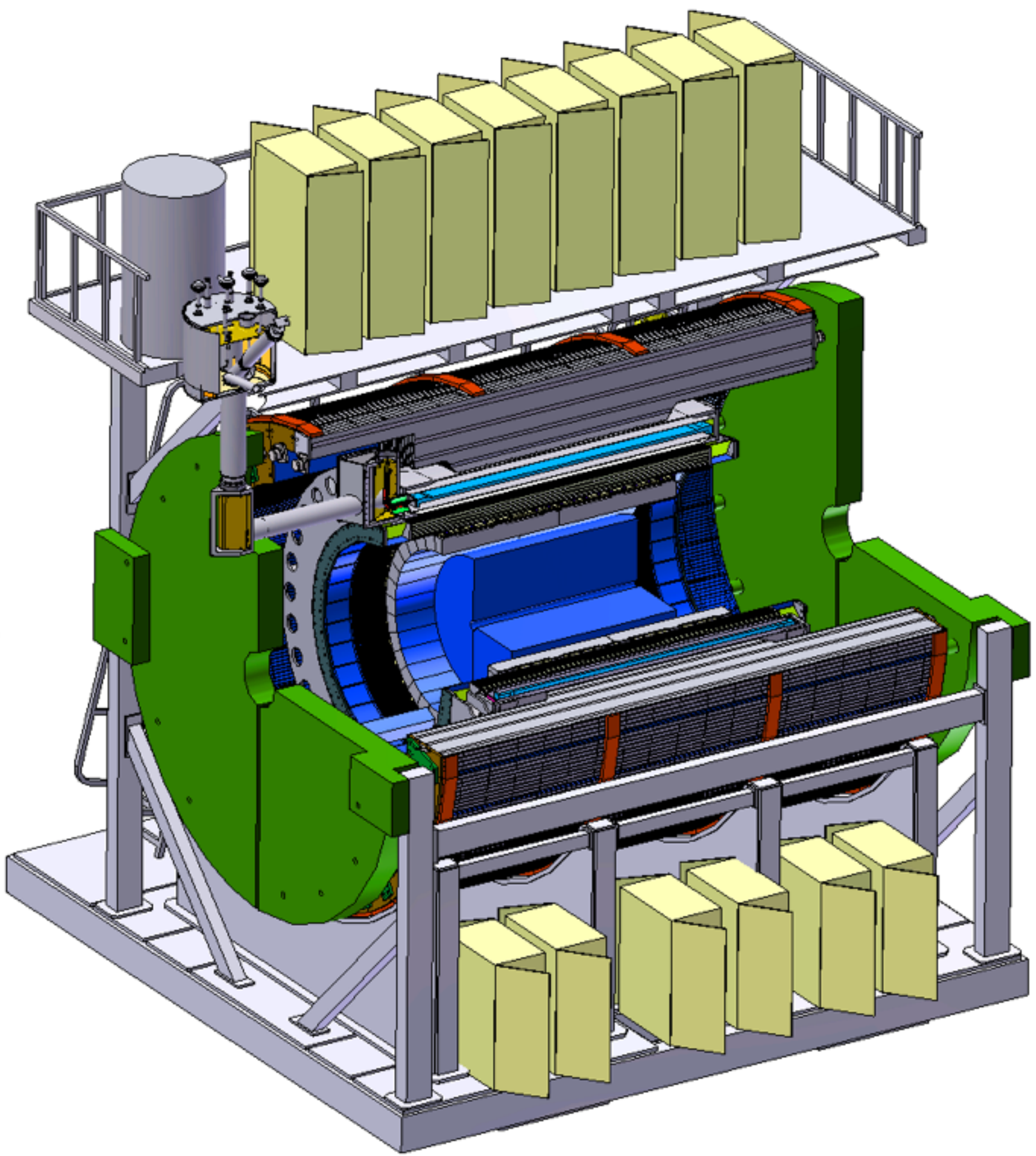
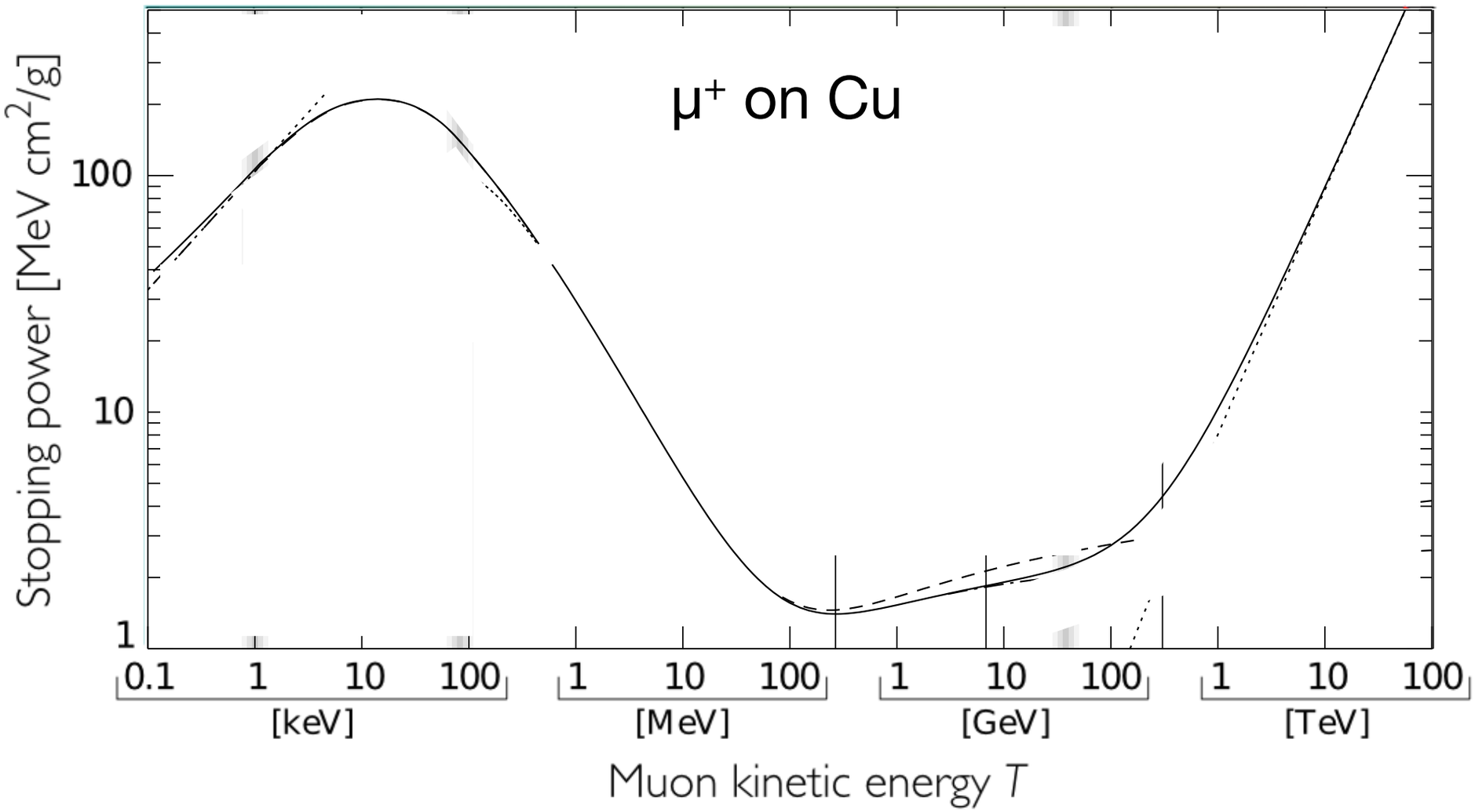
sPHENIX

Dave Morrison (BNL)



What does it mean to understand the QGP?

… we have a deep picture of what that means for <u>QED</u>



well-calibrated fundamental particle passing through a static medium leads to understanding of physics over huge range of scales

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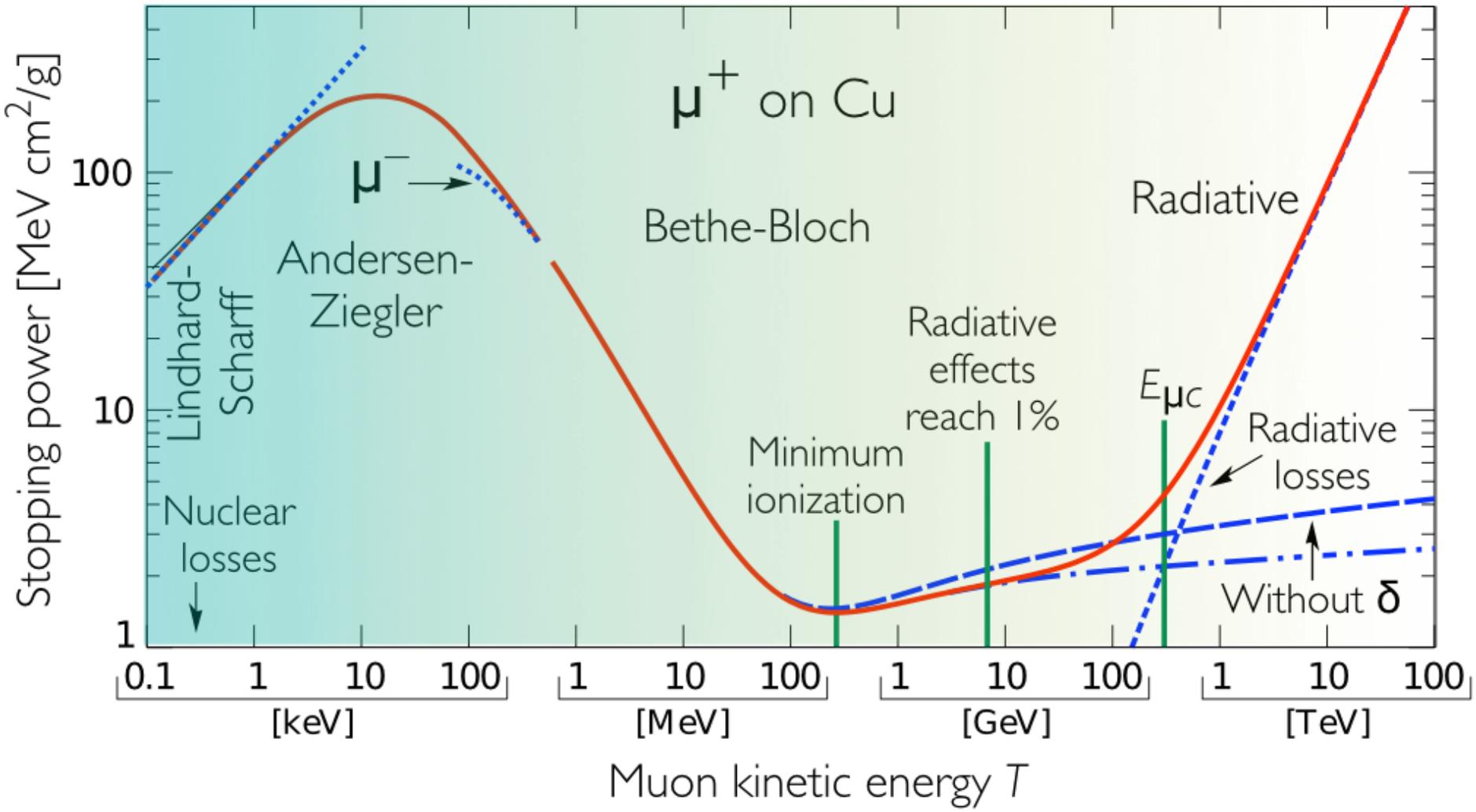
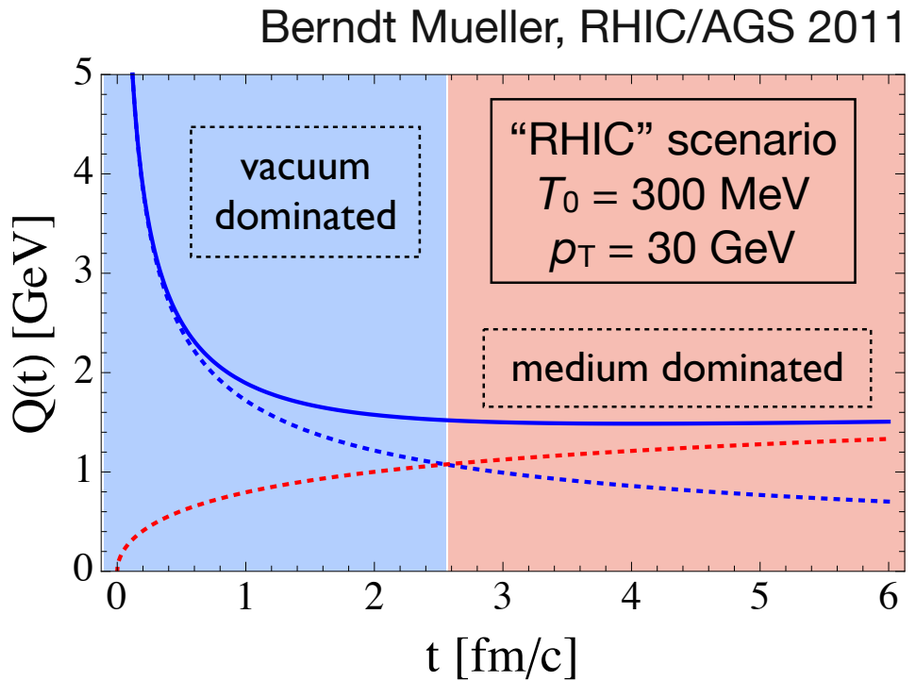
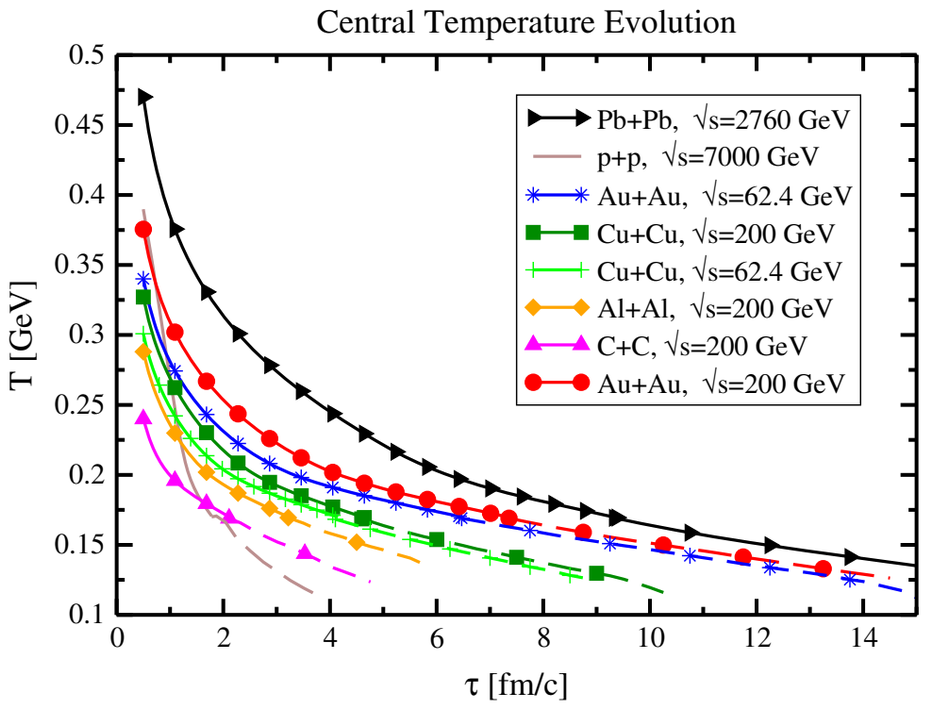


well-calibrated fundamental particle passing through a static medium leads to understanding of physics over huge range of scales

Combining time evolution of virtuality and temperature





Habish, Nagle, Romatschke, Eur. Phys. J. **C75** (2015) 1

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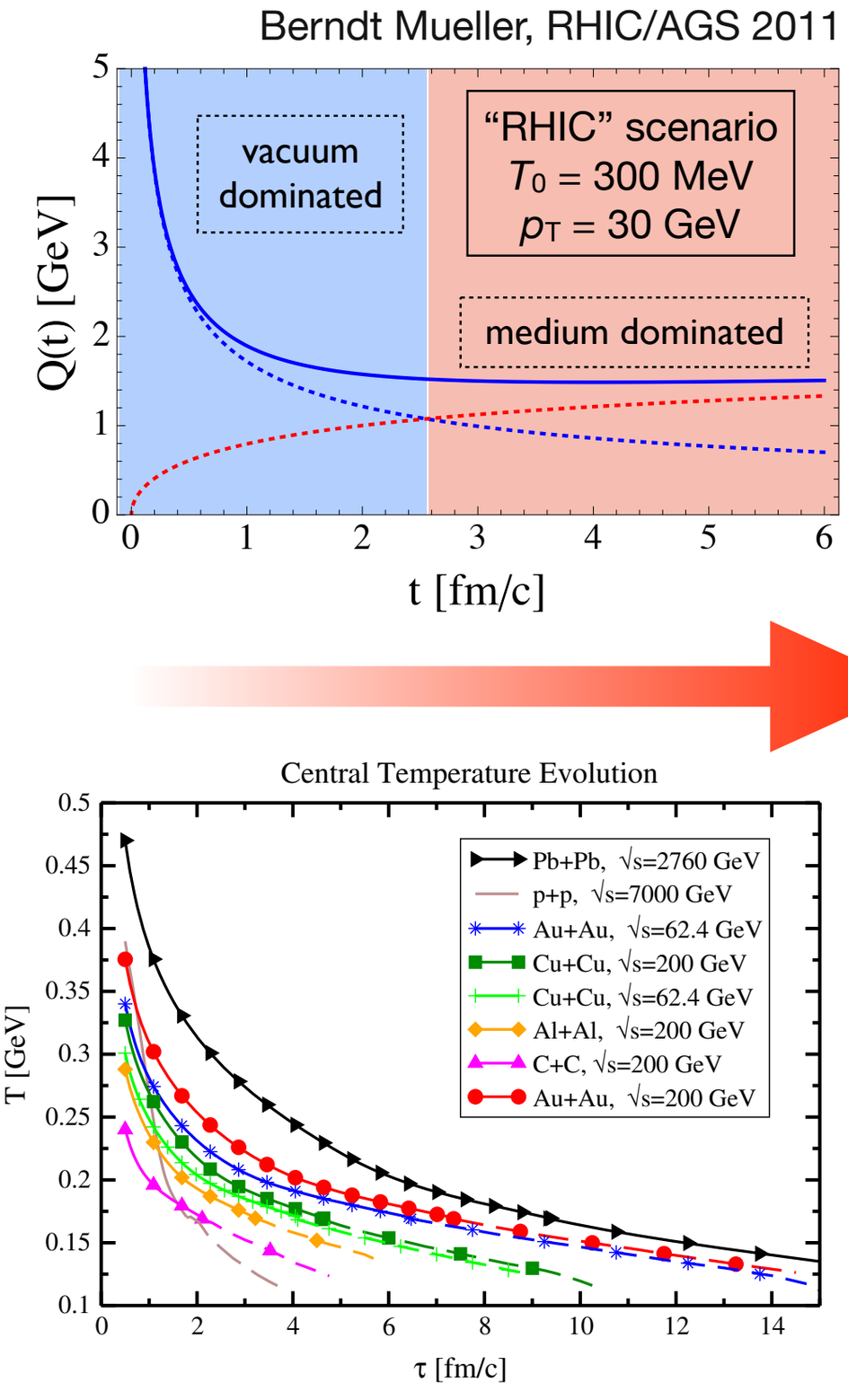

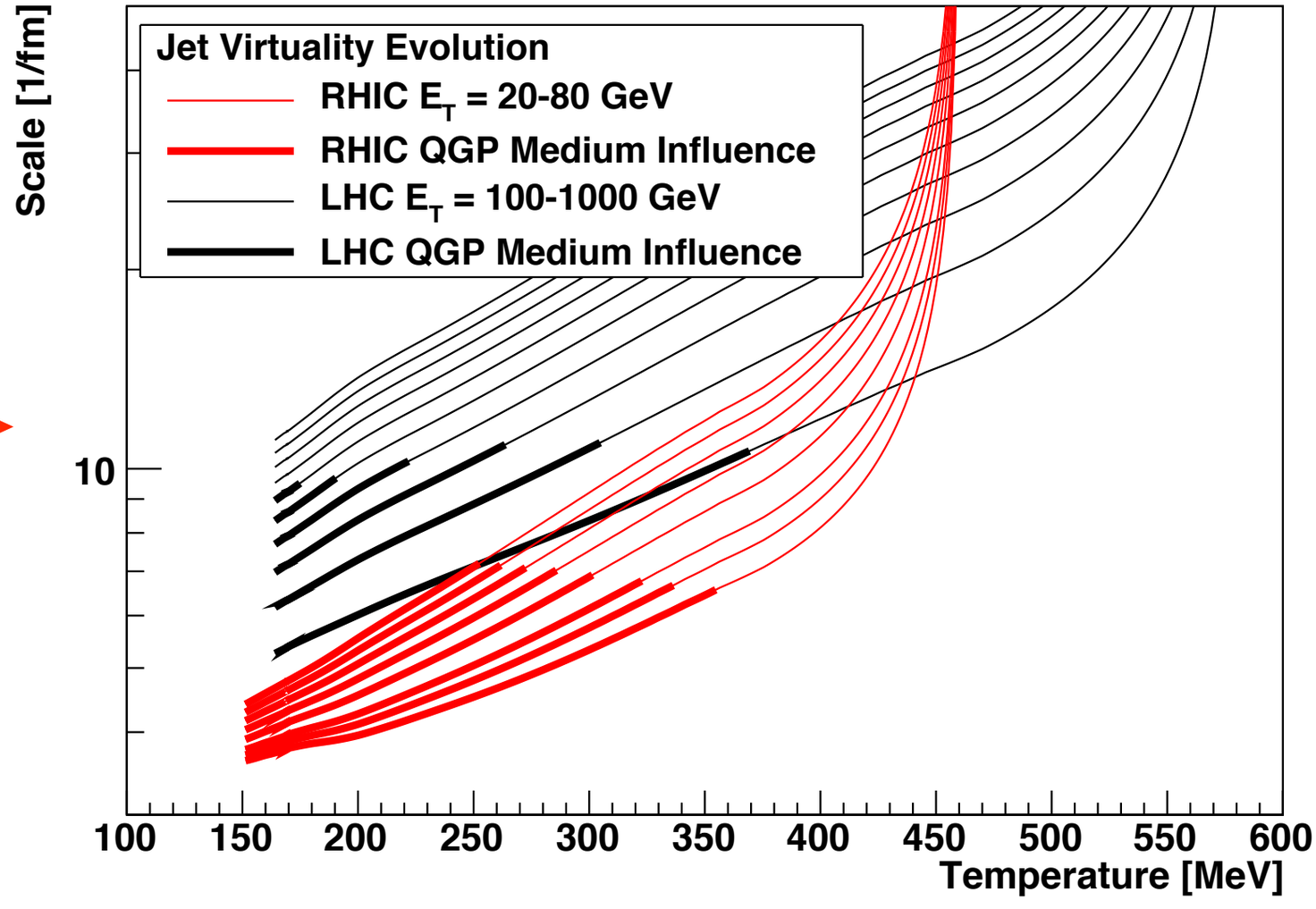

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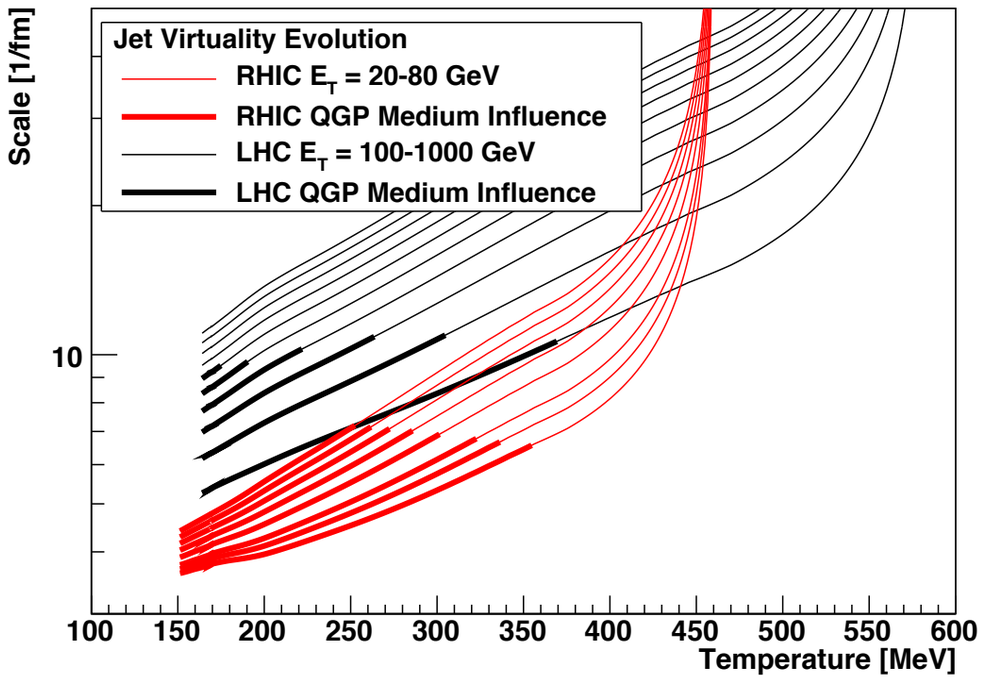

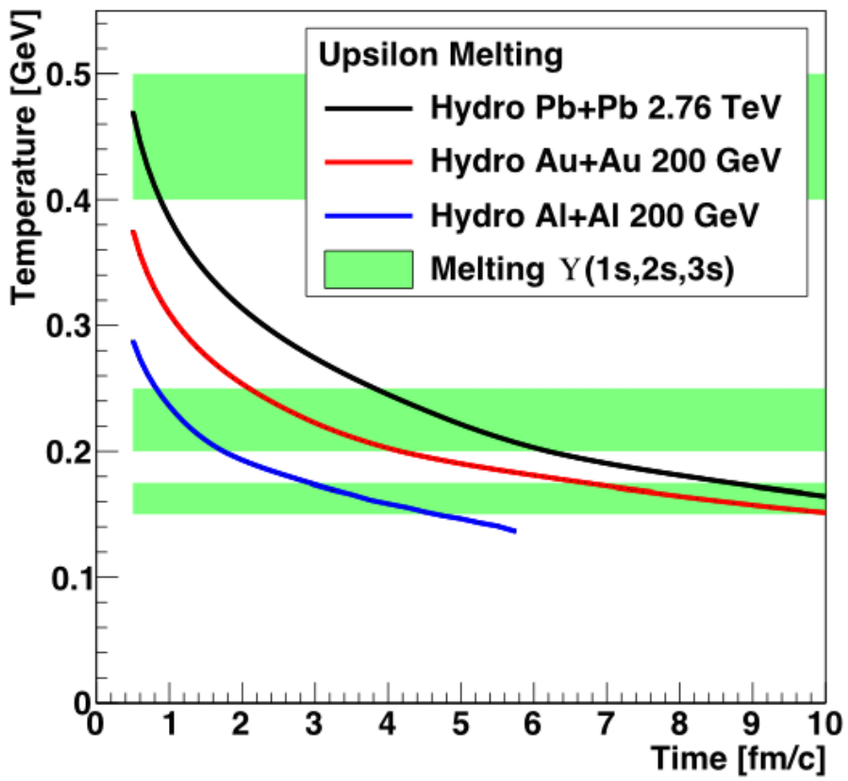

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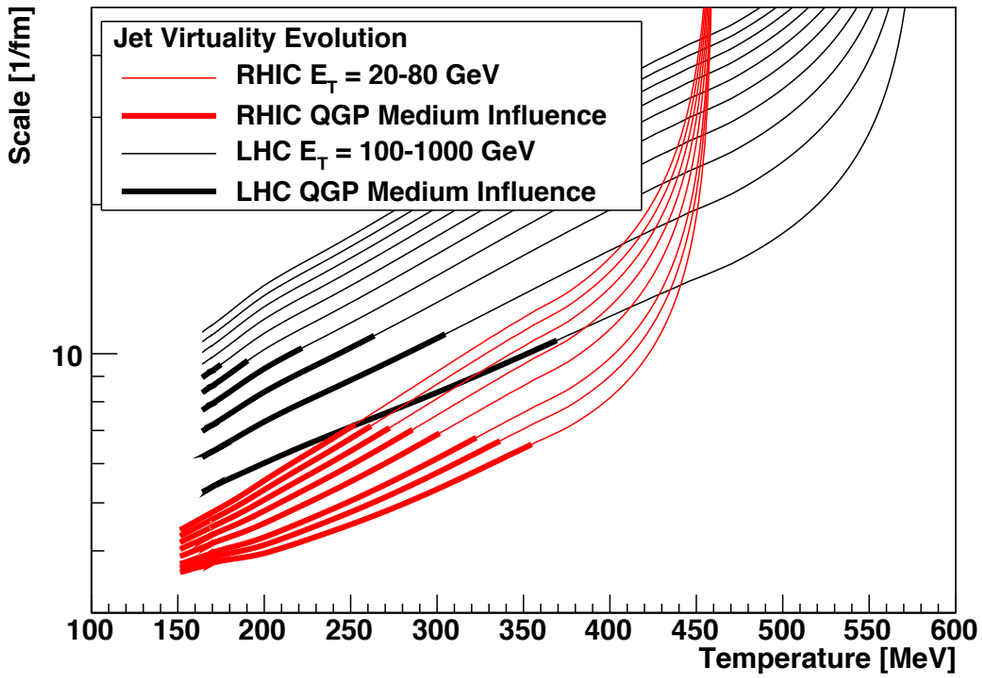
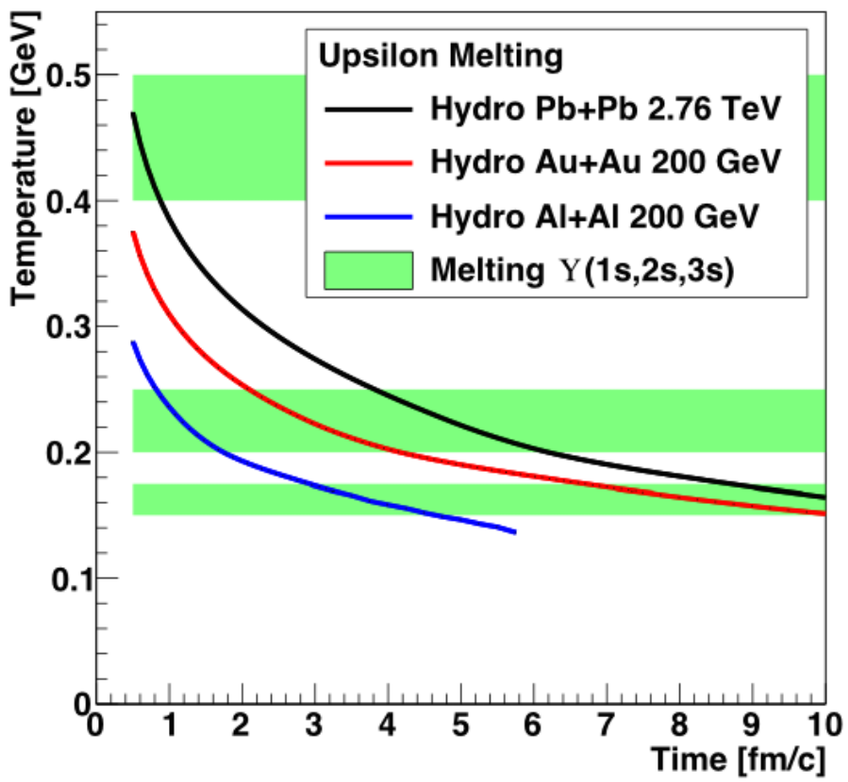
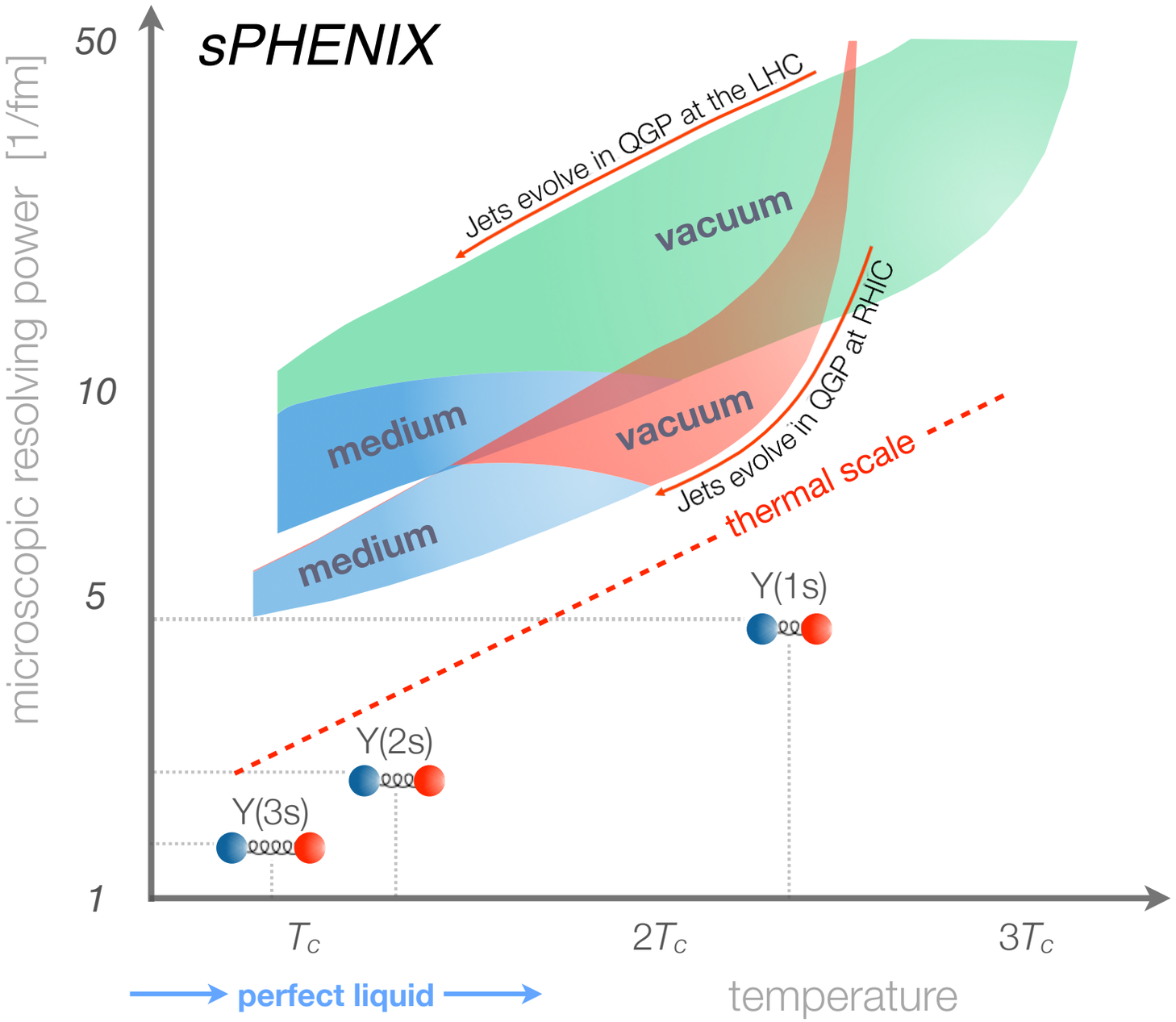






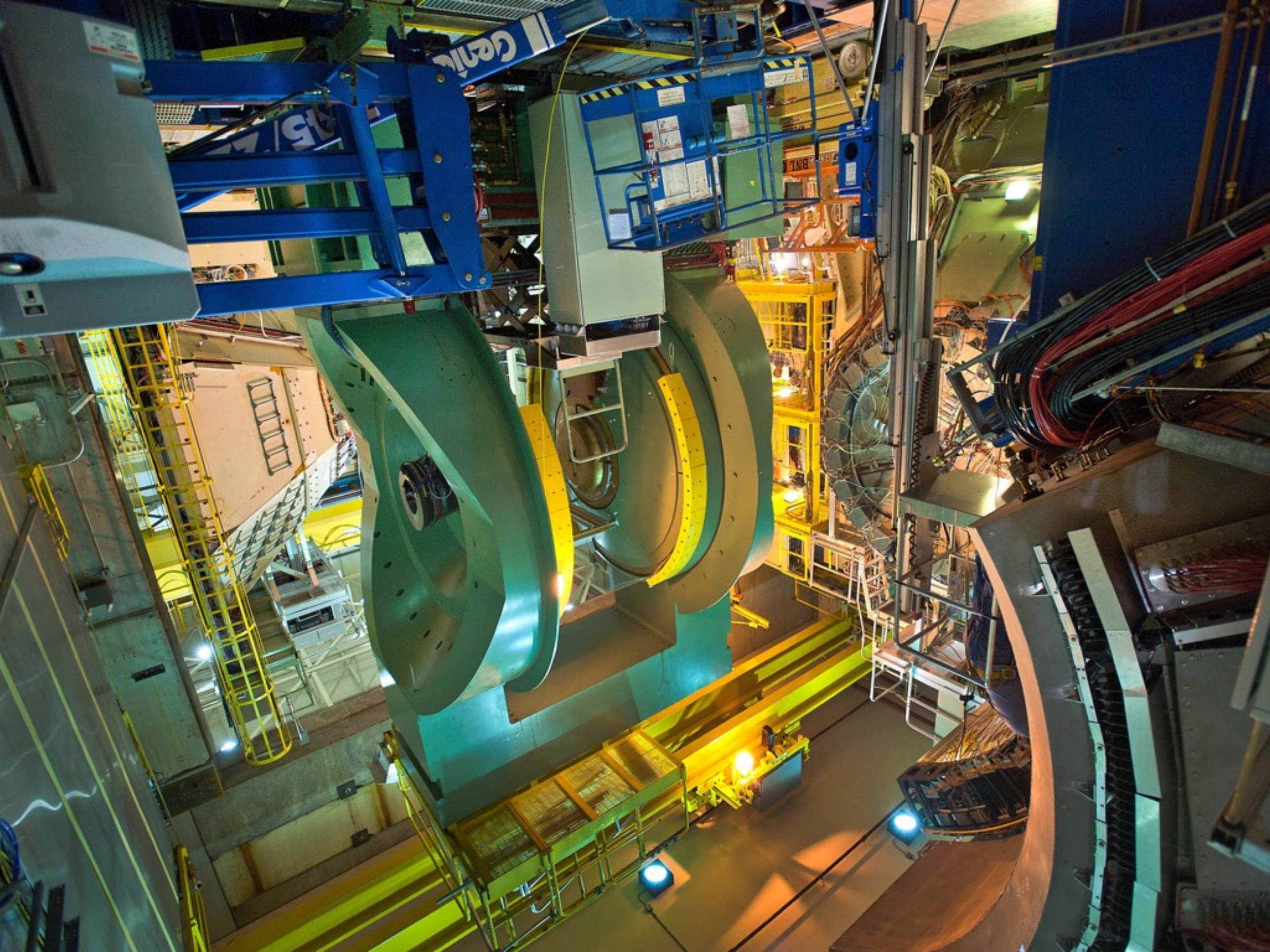
There's the future … and then there's the future

BNL's plan for the coming decade

2016 will be the last run of PHENIX

sPHENIX runs in 2021-2022

Years	Beam Species and Energies	Science Goals	New Systems Commissioned
2014	Au+Au at 15 GeV Au+Au at 200 GeV ^{3}He+Au at 200 GeV	Heavy flavor flow, energy loss, thermalization, etc. Quarkonium studies QCD critical point search	Electron lenses 56 MHz SRF STAR HFT STAR MTD
2015-16	p↑+p↑ at 200 GeV p↑+Au, p↑+Al at 200 GeV High statistics Au+Au Au+Au at 62 GeV ?	Extract η/s(T) + constrain initial quantum fluctuations Complete heavy flavor studies Sphaleron tests Parton saturation tests	PHENIX MPC-EX STAR FMS preshower Roman Pots Coherent e-cooling test
2017	p↑+p↑ at 510 GeV	Transverse spin physics Sign change in Sivers function	
2018	No Run		Low energy e-cooling install. STAR iTPC upgrade
2019-20	Au+Au at 5-20 GeV (BES-2)	Search for QCD critical point and onset of deconfinement	Low energy e-cooling
2021-22	Au+Au at 200 GeV p↑+p↑, p↑+Au at 200 GeV	Jet, di-jet, γ-jet probes of parton transport and energy loss mechanism Color screening for different quarkonia Forward spin & initial state physics	sPHENIX Forward upgrades ?
≥ 2023 ?	No Runs		Transition to eRHIC

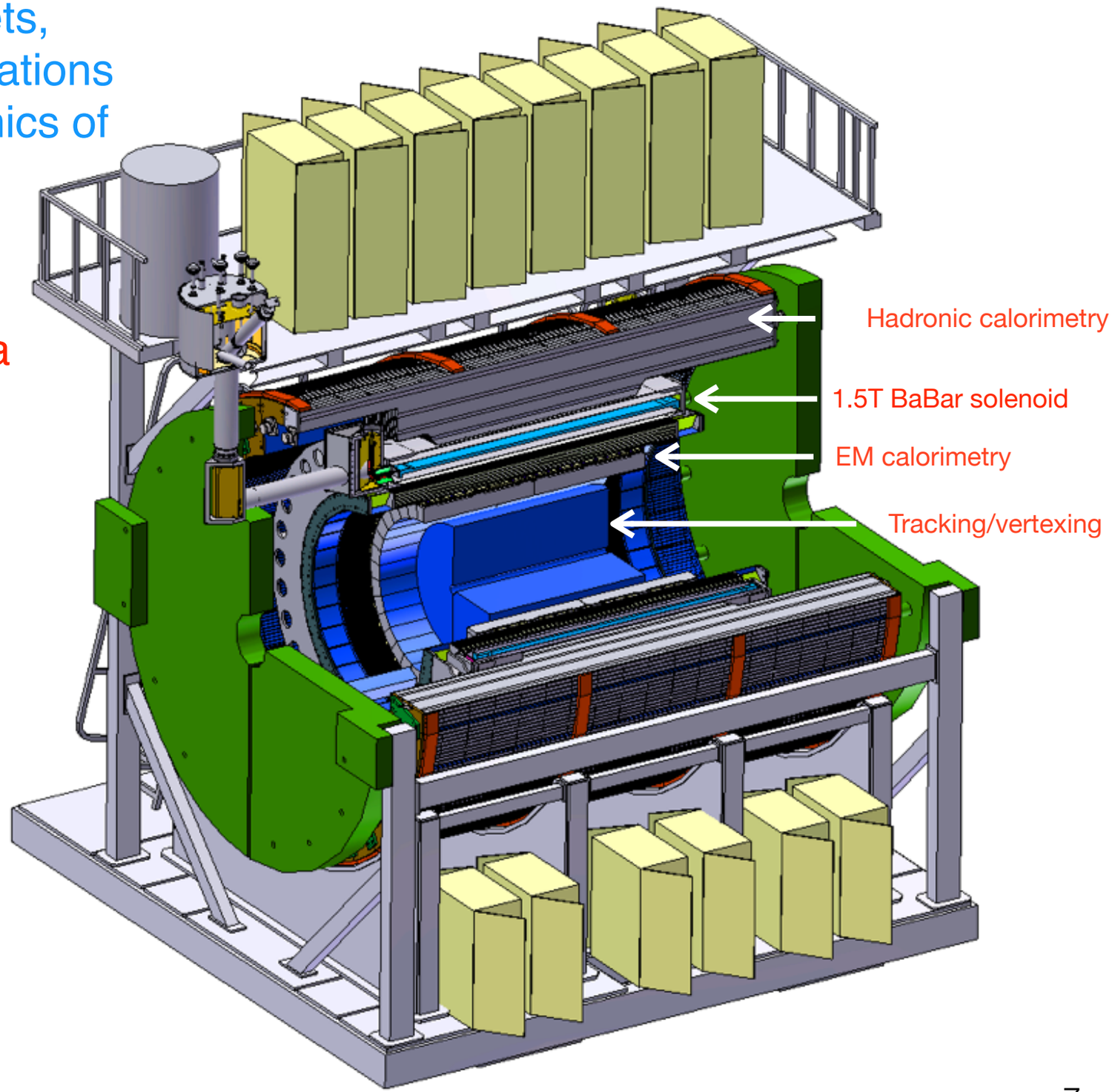


sPHENIX refresher

sPHENIX is a high-rate detector with a full program of light and heavy-flavor jets, direct photons, upsilons, and correlations to investigate the underlying dynamics of the QGP

Key observables:

- modifications of single jet spectra
- heavy-flavor tagged jets
- hadrons to high p_T
- fragmentation functions to high z
- direct photons
- high p_T Ds
- upsilons
- *X*+jet correlations



You want *rate*? I've got your rate right here.

- sPHENIX DAQ builds upon the PHENIX 15 kHz capable DAQ – able to record 100 billion Au+Au events in a 20 week RHIC year

- High RHIC luminosity ⟼ sample 0.6 *trillion* Au+Au events/year

  - relevant for measurements using the full z-vertex range (e.g. gamma+jet)

  - sample the jet spectrum to the kinematic limit

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Joey Chestnut sampling a minimum bias collection of hot dogs – it's one strategy

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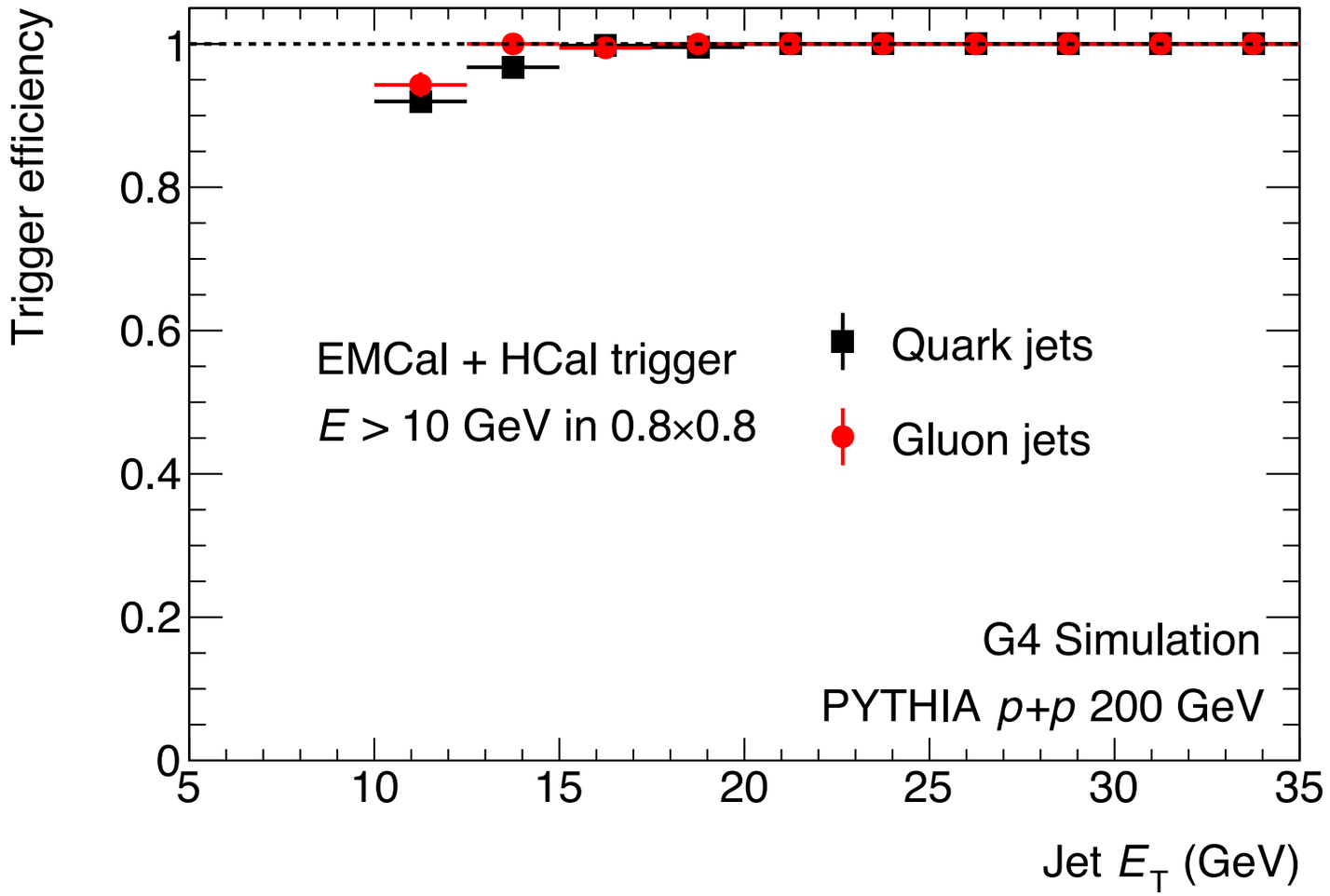
Matt Stonie – a new generation

Unbiased triggering with deep calorimetry

Jet patch trigger in *p*+*p*



Triggering needed in *p*+*p* and *p*+A – crucial to control biases introduced by triggering

Full hadronic and EM calorimetry enables very effective, very low bias triggering

Enables full exploitation of excellent RHIC luminosity

Unbiased triggering with deep calorimetry

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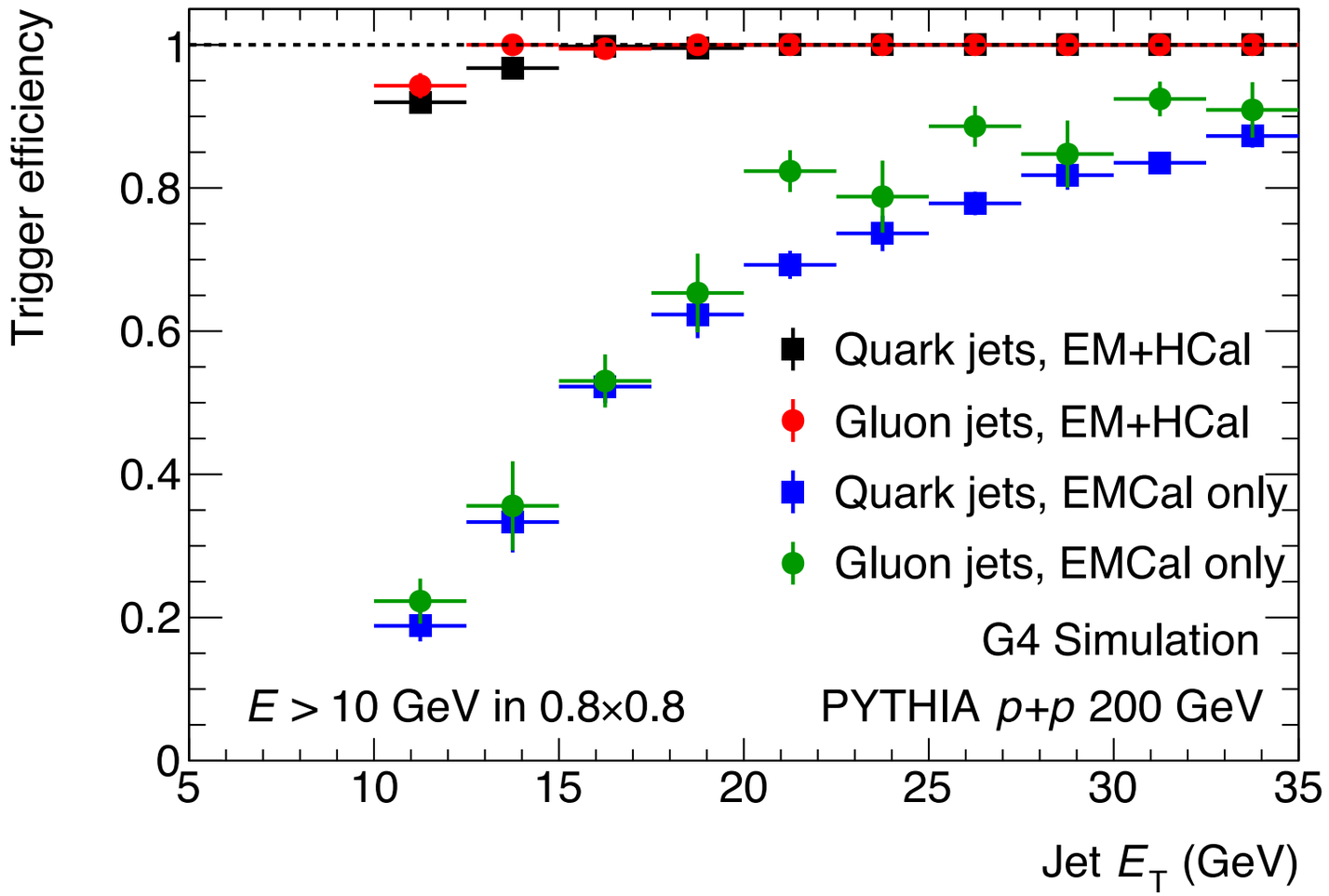

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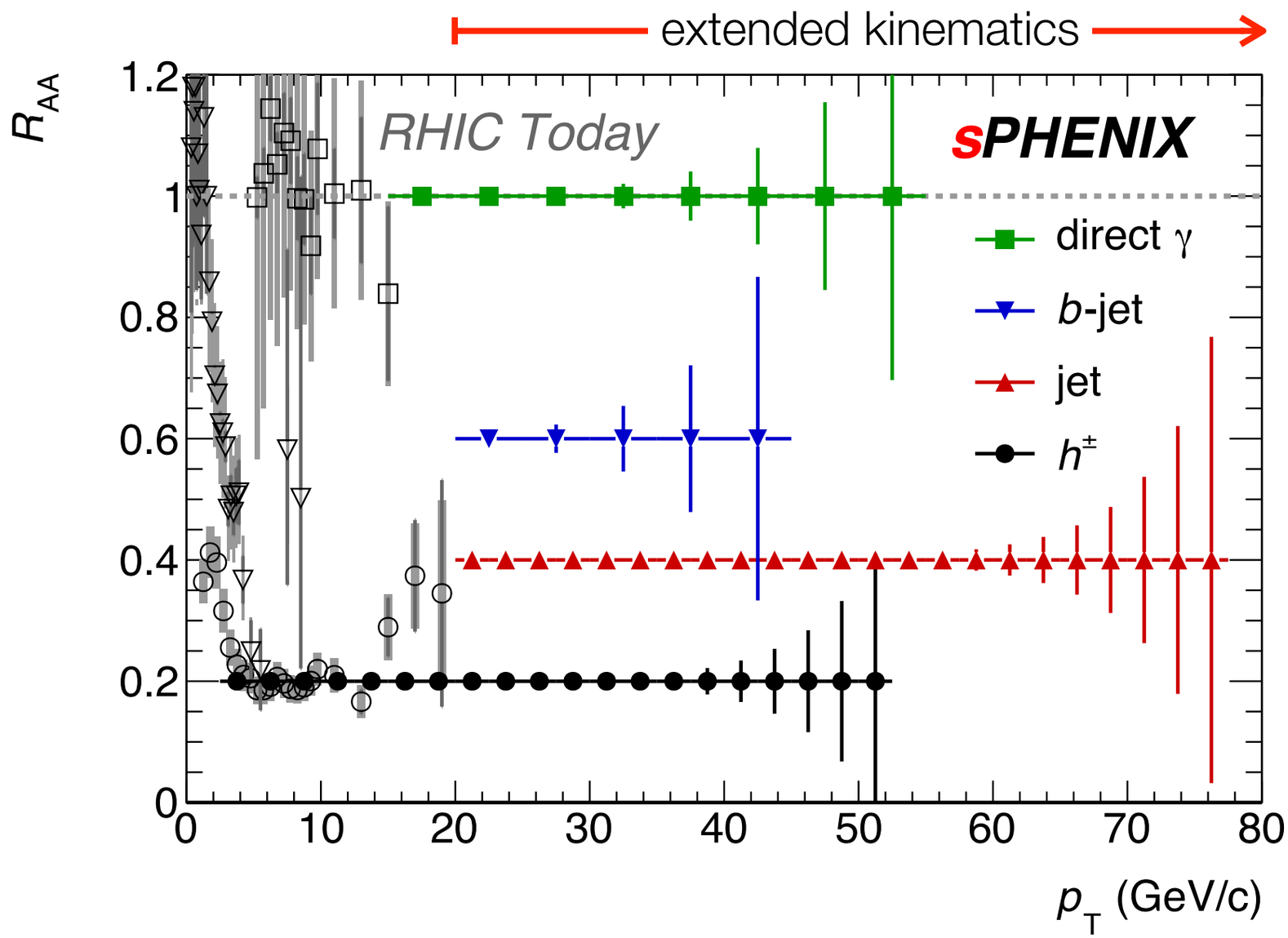
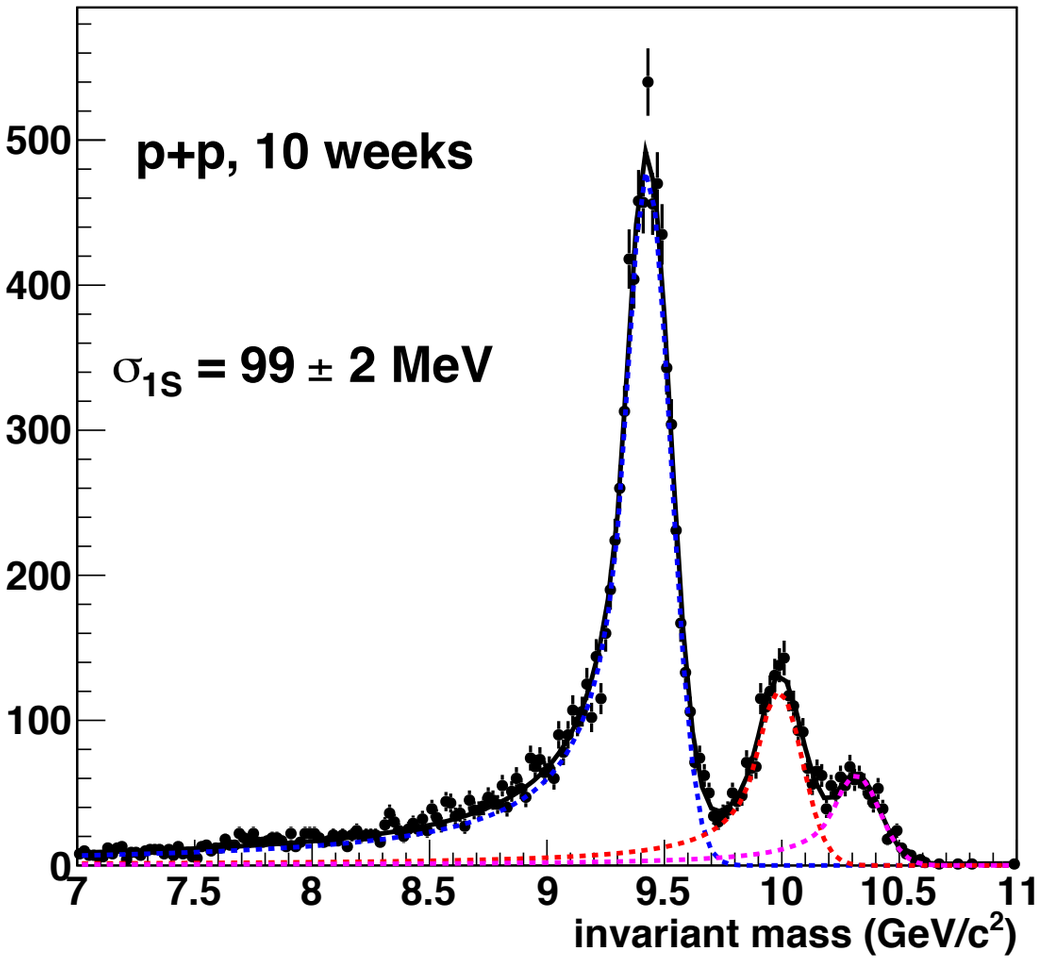
Resolving power and kinematics

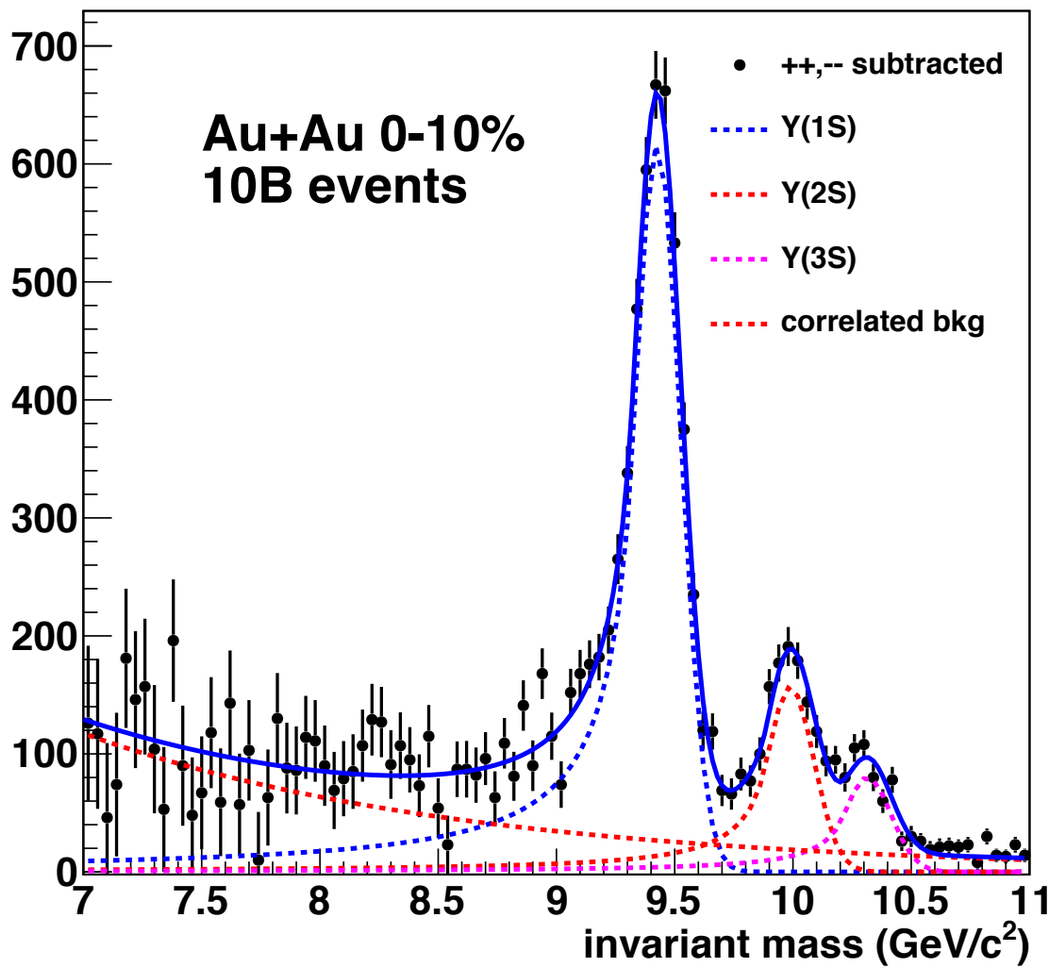
high-rate DAQ, full calorimetry, exploiting high RHIC luminosity

$\Longrightarrow$ *huge range of microscope "resolving power"*



Fully resolved Upsilon mass states



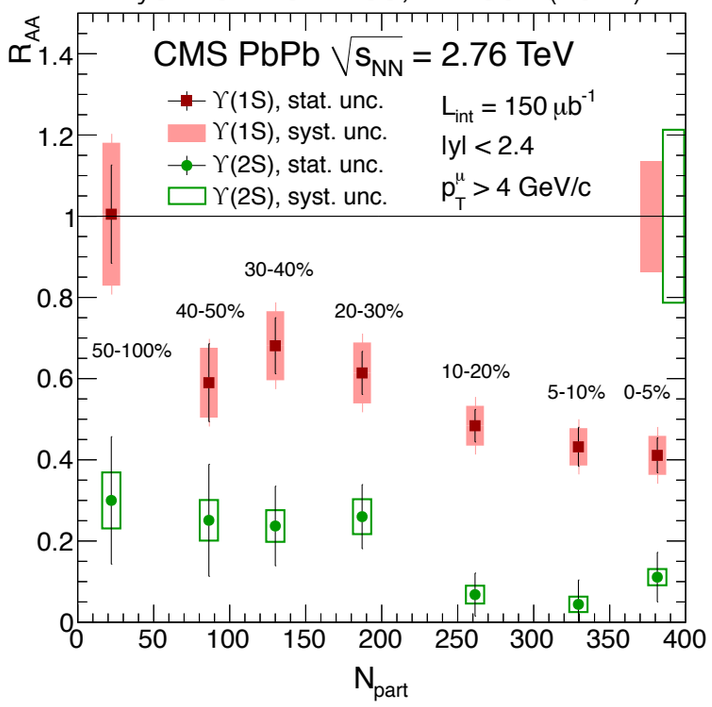


Upsilon statistics in *p+p* – the denominator in determining R_{AA} – benefits from recent C-AD luminosity projections. In Au+Au, record outright 100 billion minimum bias events. Mass resolution better than 100 MeV/c^2.

Color screening – RHIC and LHC

Pronounced suppression of Y(1S) and Y(2S).
Negligible recombination at RHIC and LHC.
Much more data coming in Run 3

Phys. Rev. Lett. 109, 222301 (2012)



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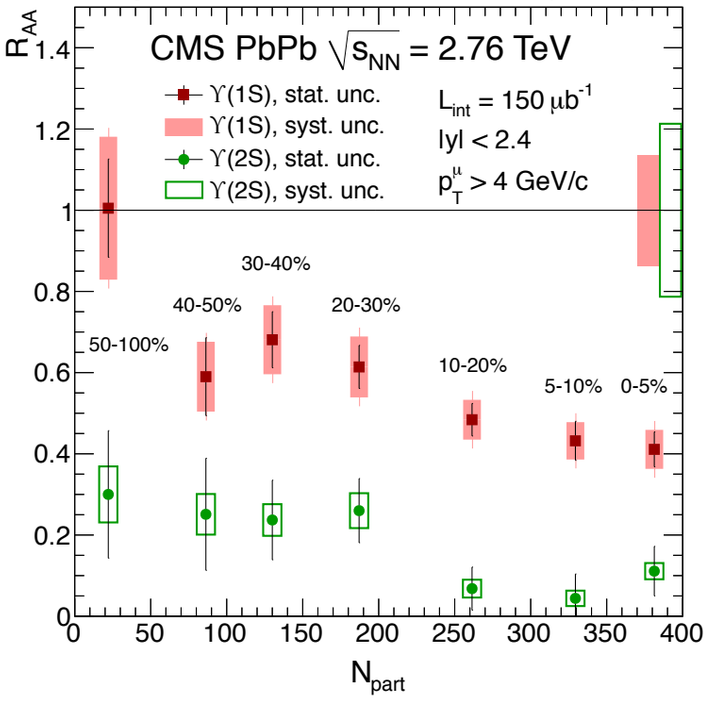
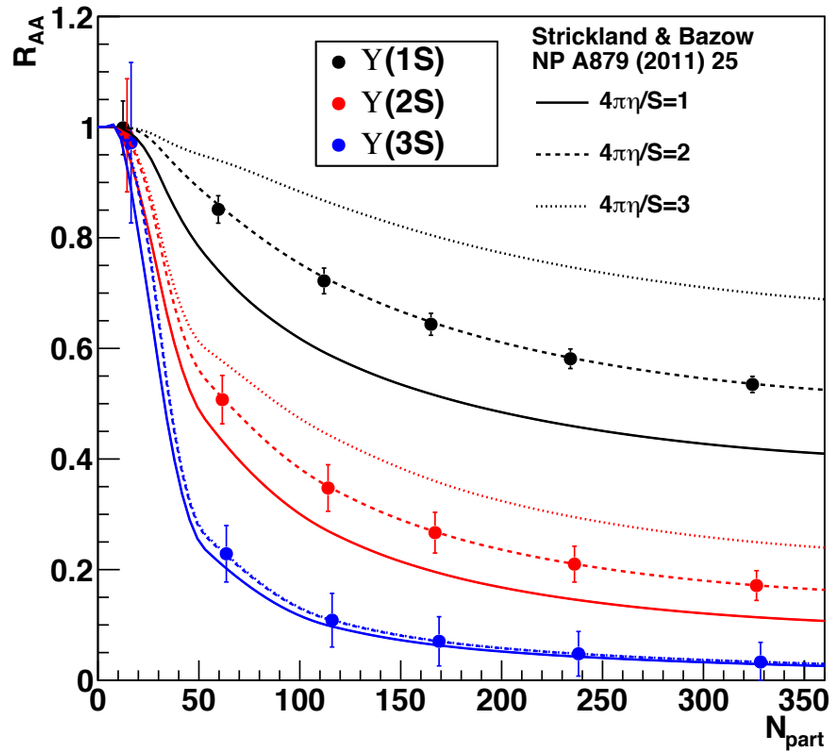


sPHENIX – projected Y yields and S/B compared to Strickland and Bazow model



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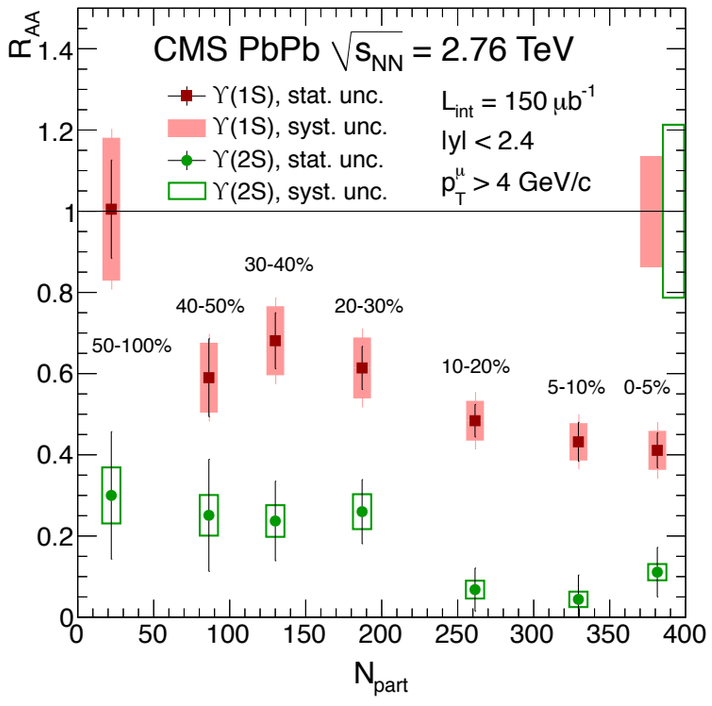

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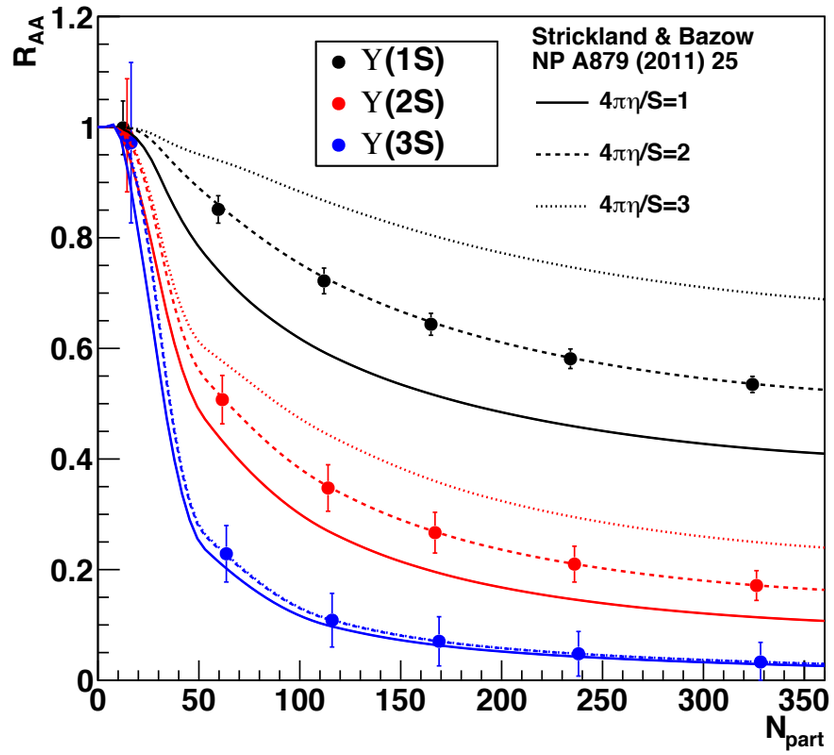
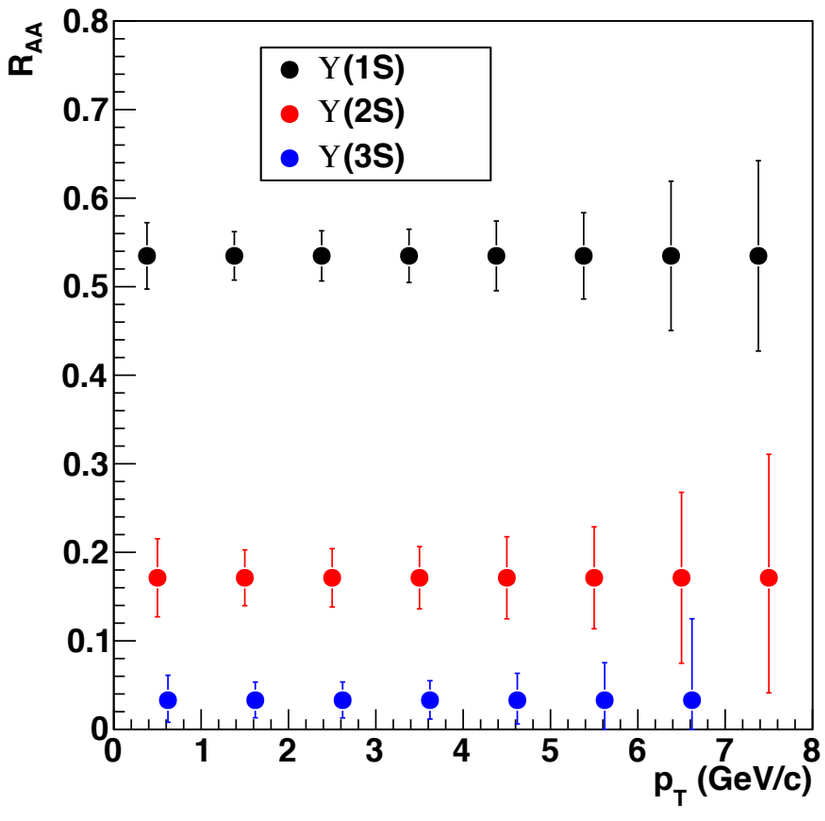


sPHENIX – p_T dependence of Y R_{AA} for central events



Jets in both *p+p* and in heavy-ion collisions

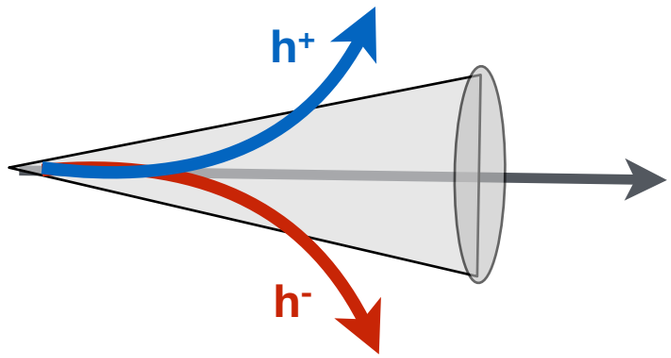
- One method for identifying single jets in HI background published as Phys. Rev. C86 (2012) 024908 (“ATLAS” approach)

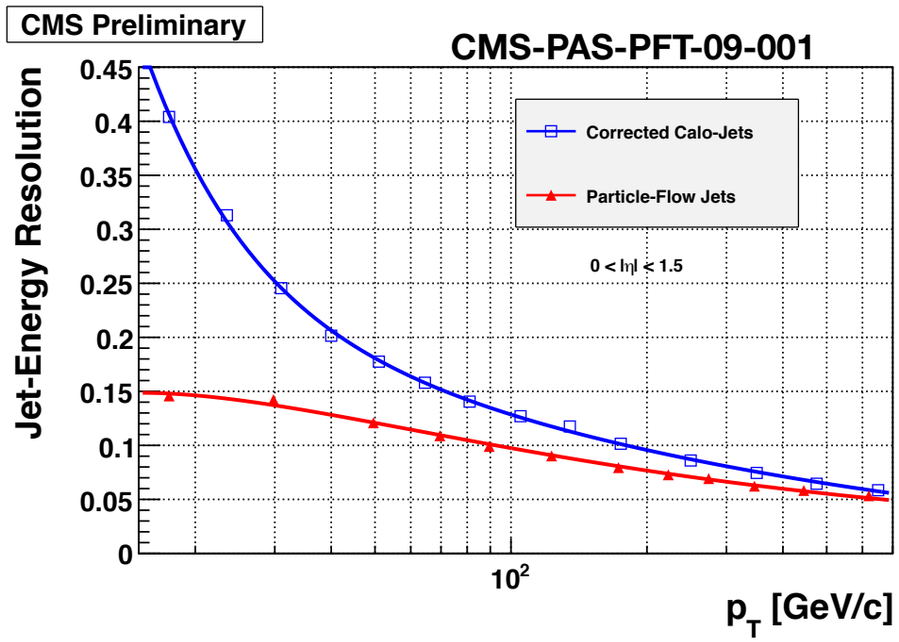
- sPHENIX can use other methods, too
  - ensemble approach (STAR, ALICE)
  - particle-flow algorithms (CMS)
  - fake jet rejection

Particle flow applied to sPHENIX

Improved Energy Resolution via:

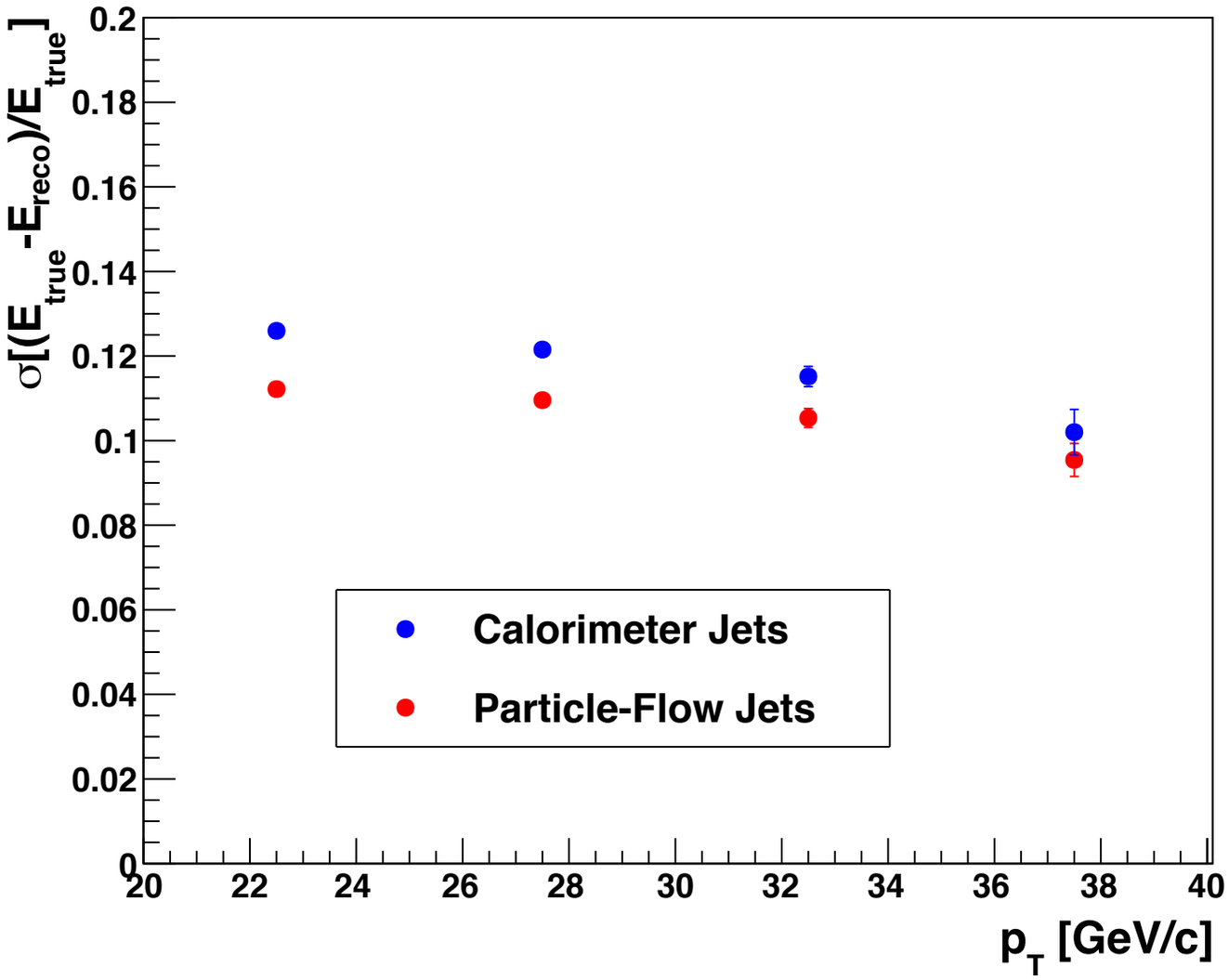
- improve upon the calorimeter resolution
- remove magnetic field deflections





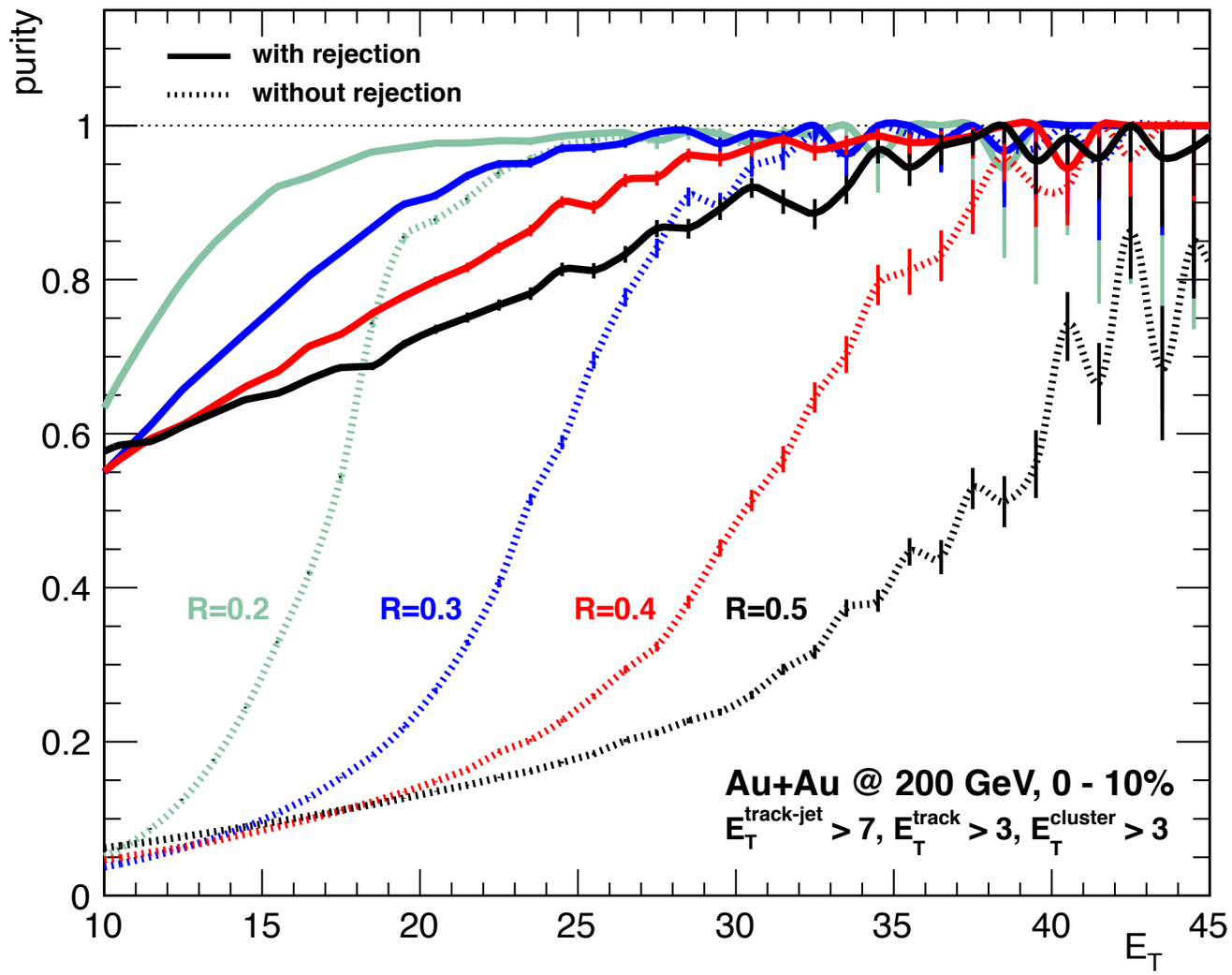
big effect in CMS – large magnetic field pulls jet constituents apart

~10% improvement in jet energy resolution for sPHENIX



Fake jet rejection

- Various approaches
- Place hardness requirement on jet constituents
- Resulting jets are biased, but manipulating that bias is a way to access physics



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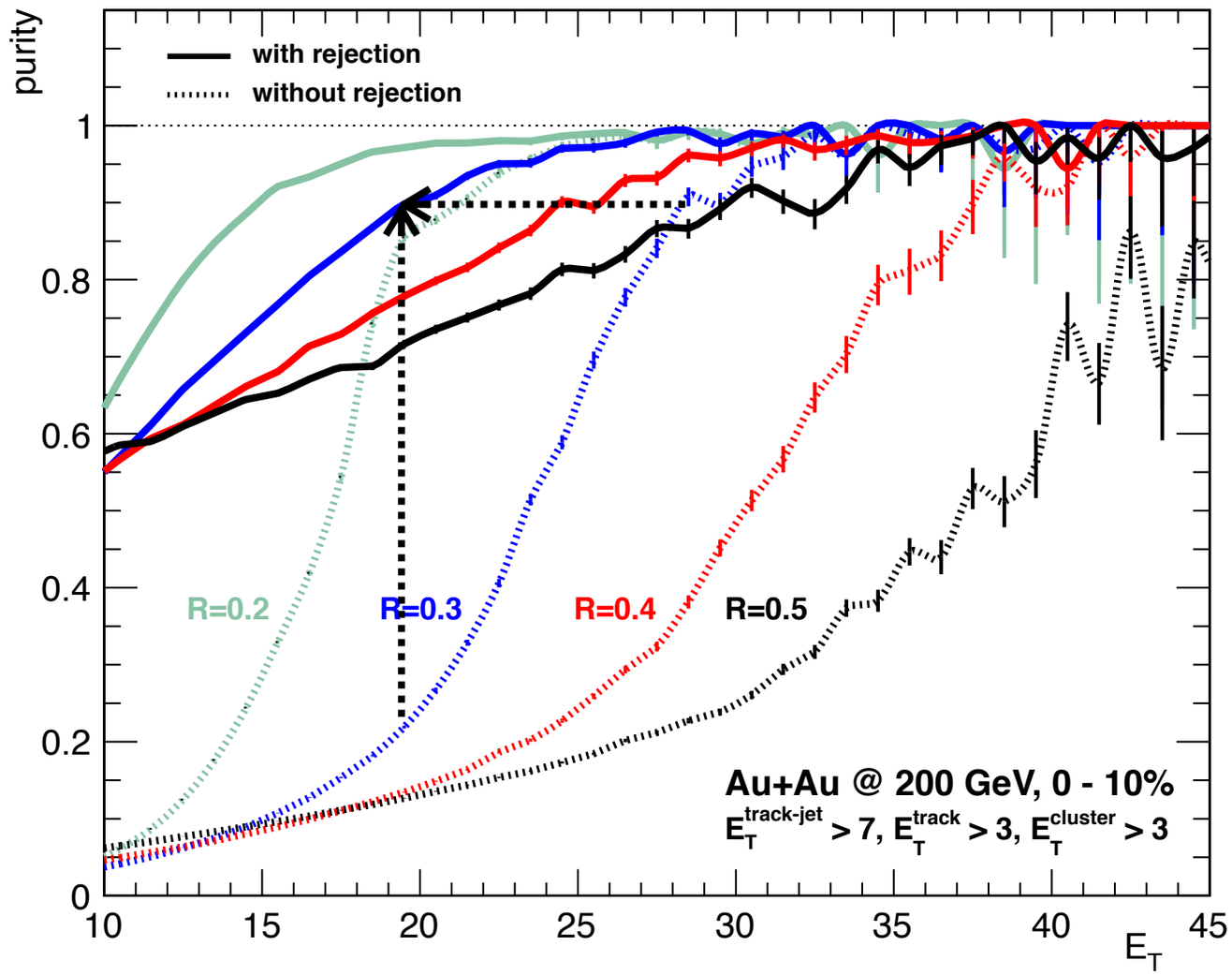
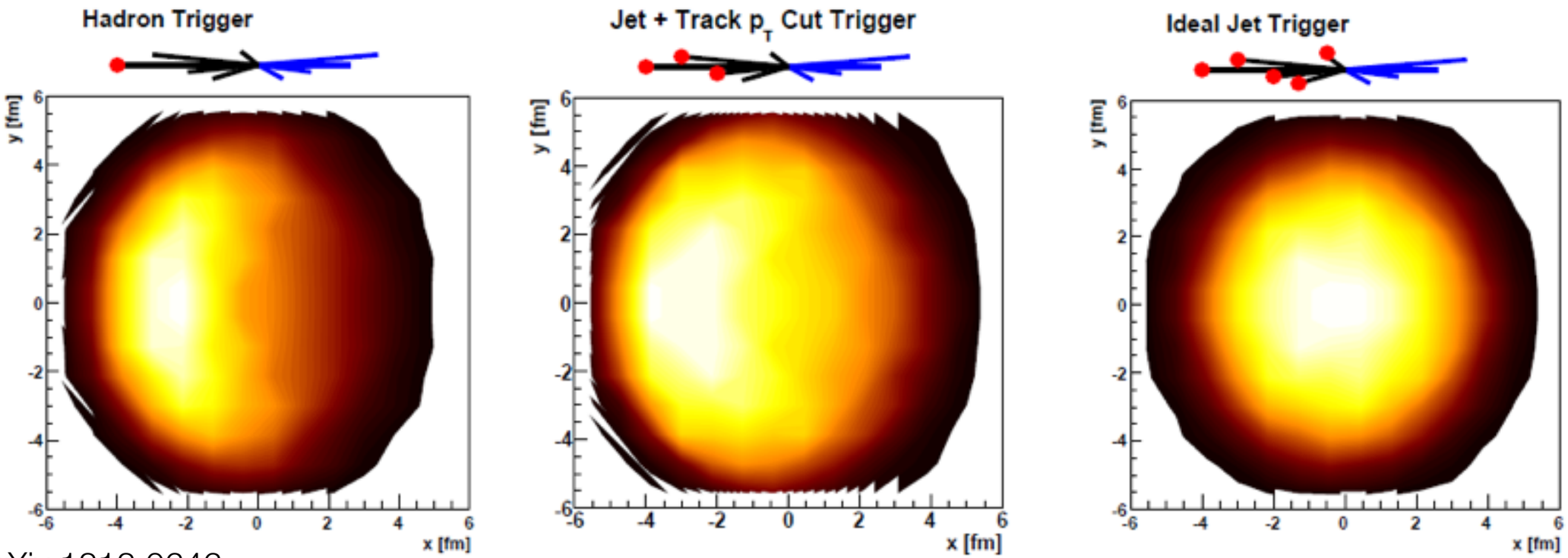


Deliberately biasing jets as investigative tool

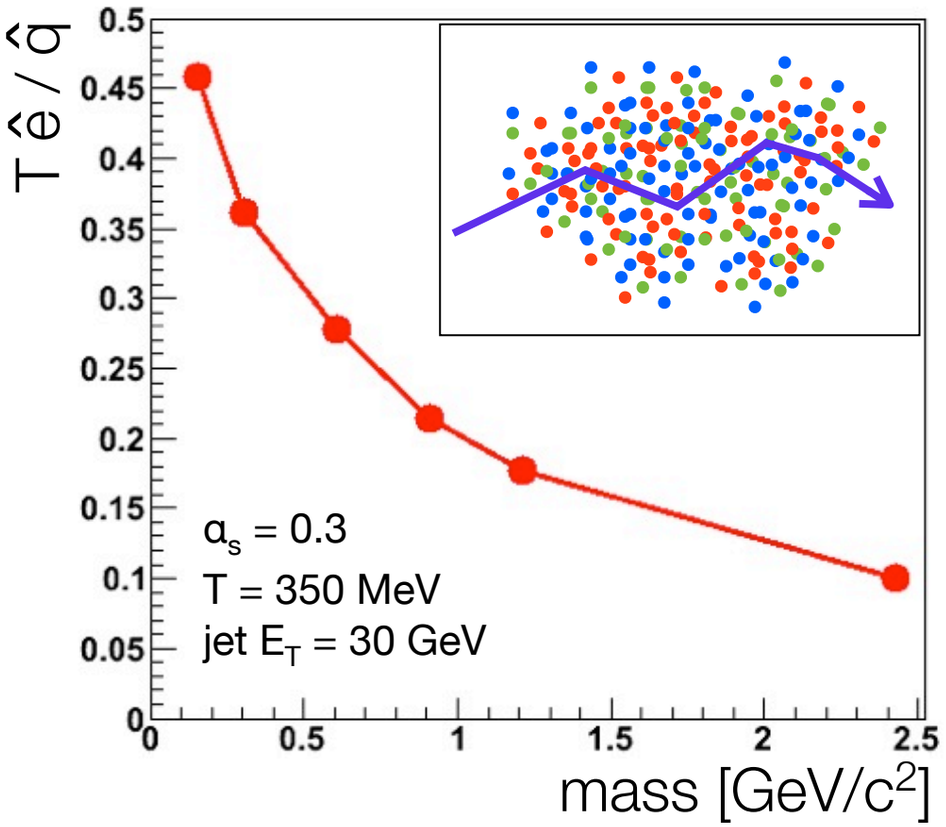


arXiv:1212.0646

Thorsten Renk – (x,y) of initial hard scattering for an object going to left. How you define and detect that object biases the set of initial hard scattering locations.

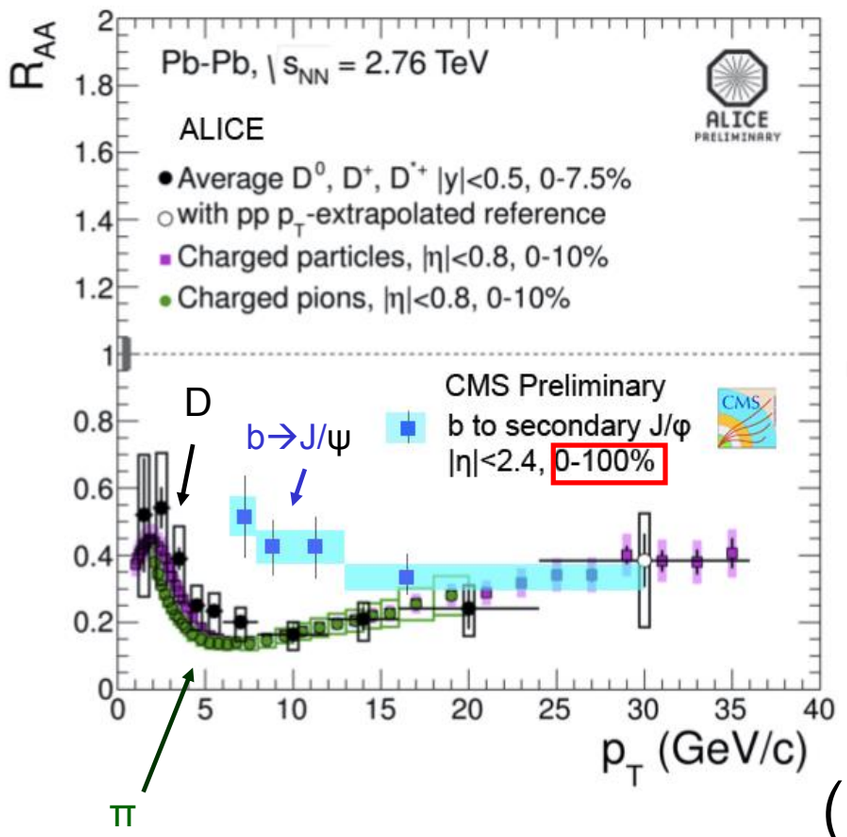
The steeper the p_T spectrum, the more pronounced the effect.

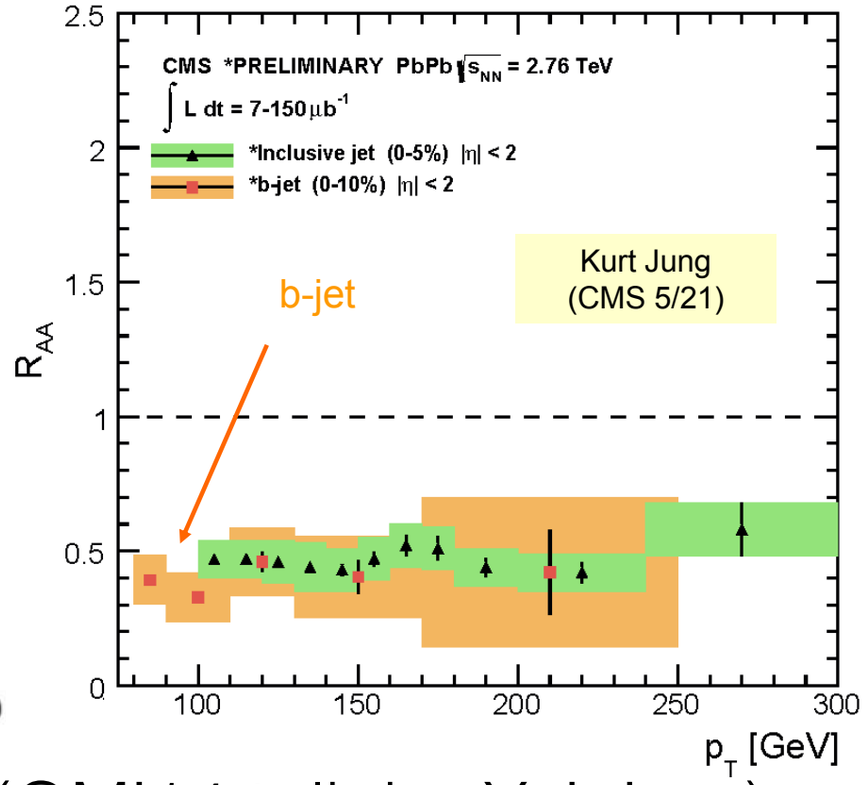
b-jet physics



C. Coleman-Smith
arXiv:1108.5662

- The quenching of heavy quark jets is different:
  - ➡ suppression of radiation at small angles
  - ➡ different sensitivity to *radiative* vs. *collisional* energy loss
- LHC measurements of *b*-jet R_{AA} are at > 80 GeV, consistent with light jets
  - ➡ full *b*-jets at RHIC *probe needed kinematic range*

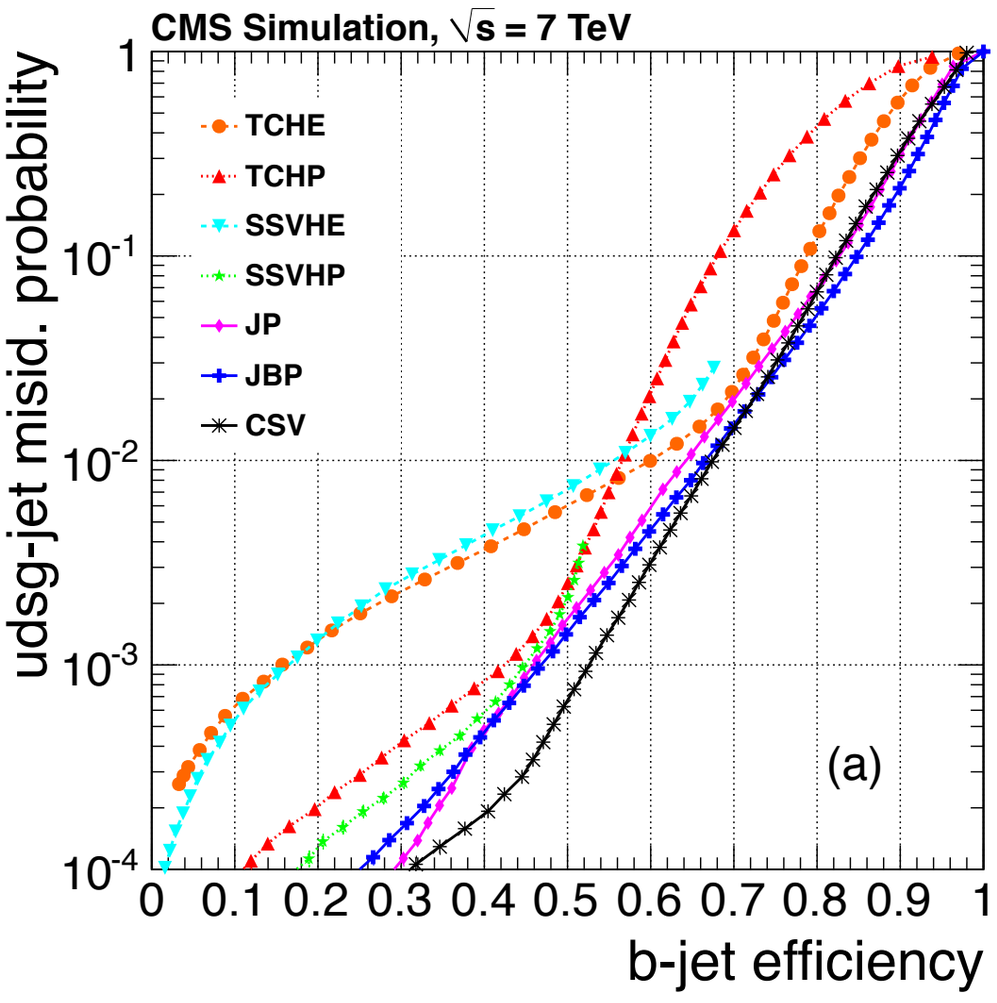




(QM'14 talk by Y-J. Lee)

Heavy flavor jets in sPHENIX

JINST 8 (2013) P04013

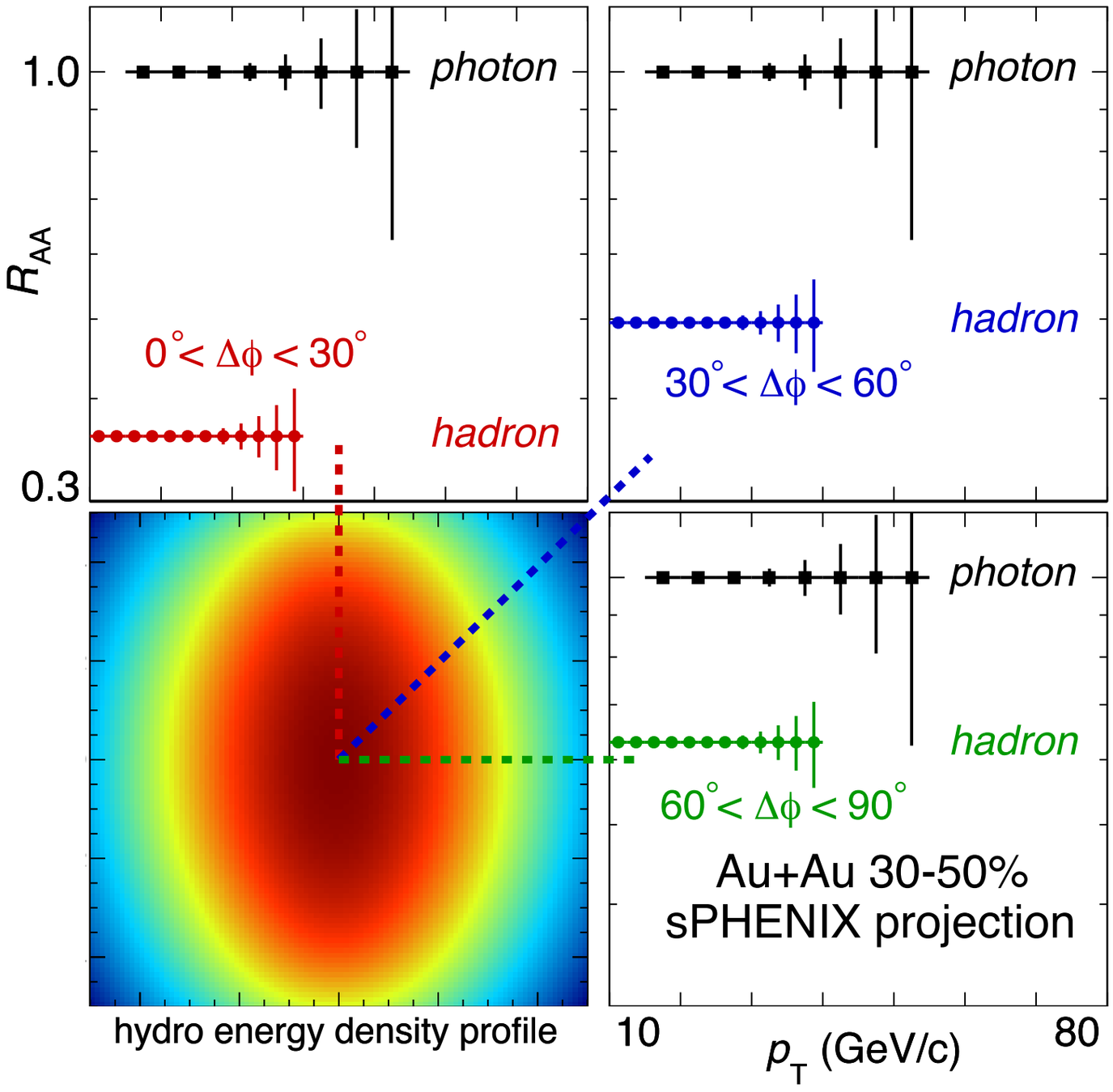


Variety of algorithms for identifying HF jets – B,D mesons have long lifetimes and distinctive decays

With excellent calorimetry and tracking, sPHENIX is suited for using a number of modern algorithms

e.g., reconstructed secondary vertex, track counting

Not just inclusive: mid-central Au+Au collisions



Large Au+Au statistics enables more differential measurements –

Binning mid-central events by reaction plane orientation selects path length in the medium

Underlying event in mid-central events is much smaller than in central events – aids in pushing jet finding to lower jet p_T

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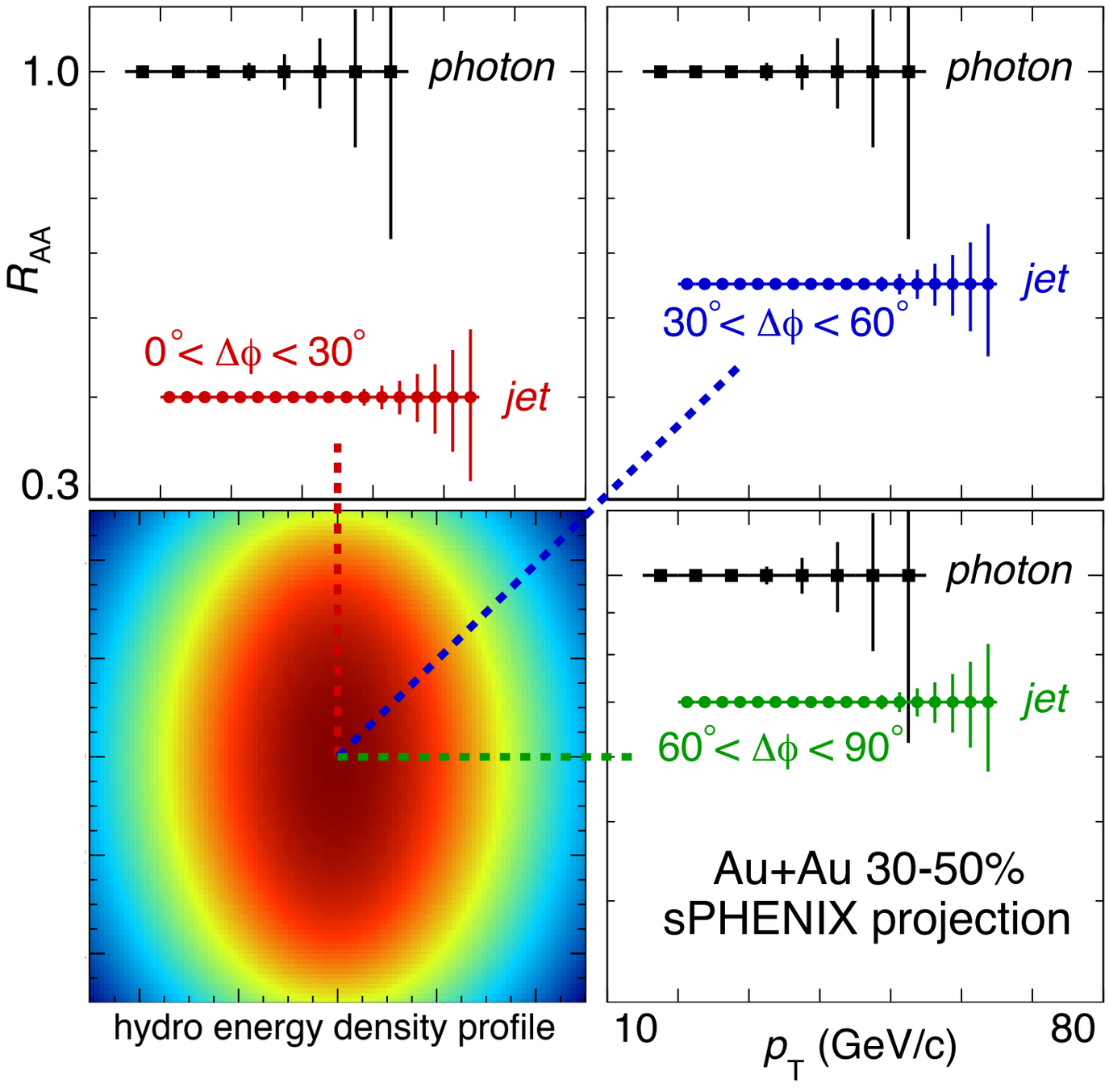

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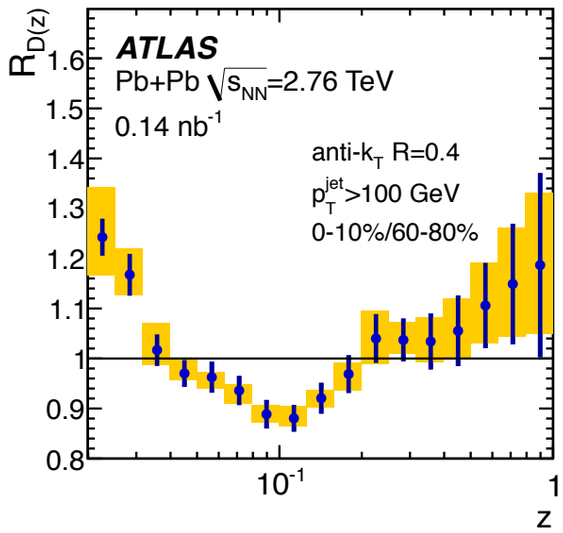
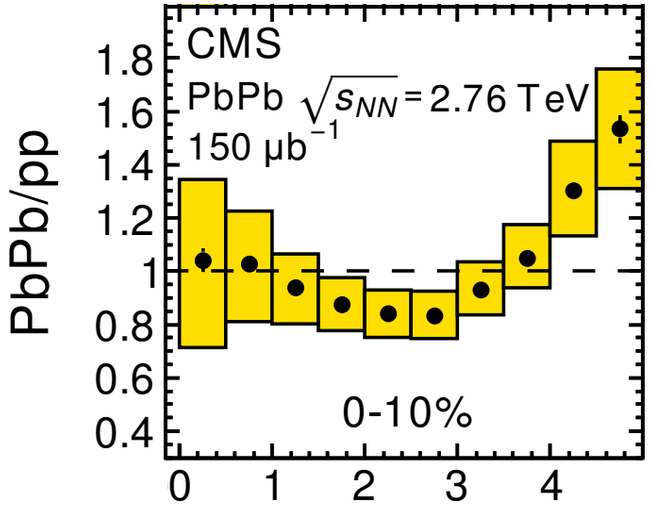
Jet fragmentation functions

hep-ex/1406.2979



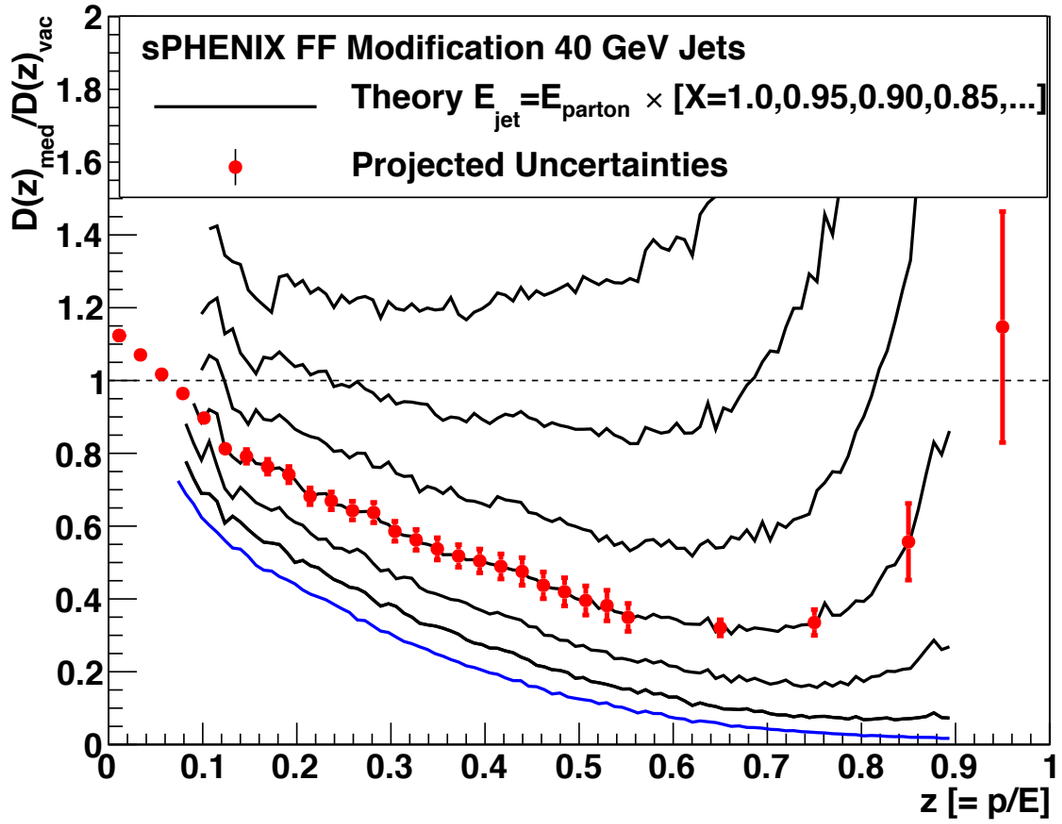
Phys. Rev., C90:024908, 2014

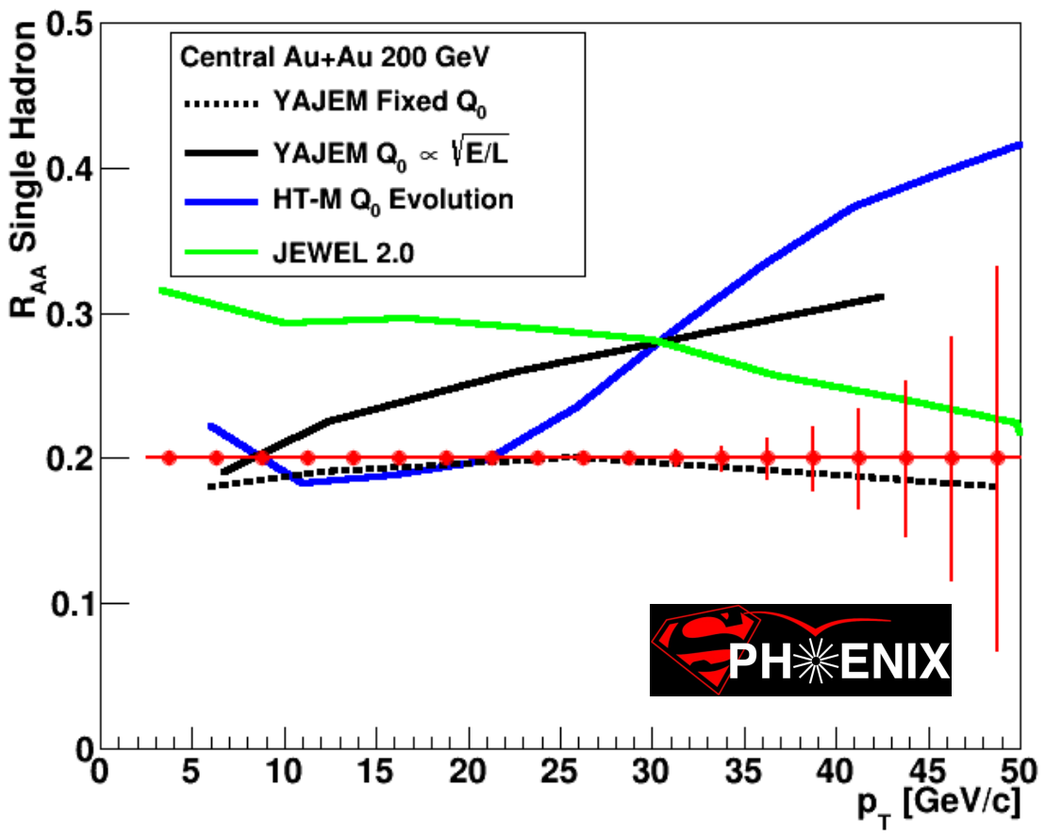


modification at all *z* values

- Fragmentation functions reveal *<u>changes in the structure</u>* of the jet – calorimetry provides baseline
- Hadron spectra sensitive to, e.g. *<u>virtuality evolution</u>* in quenching
  - ➡ both require tracking *<u>performance at high-p_T</u>*

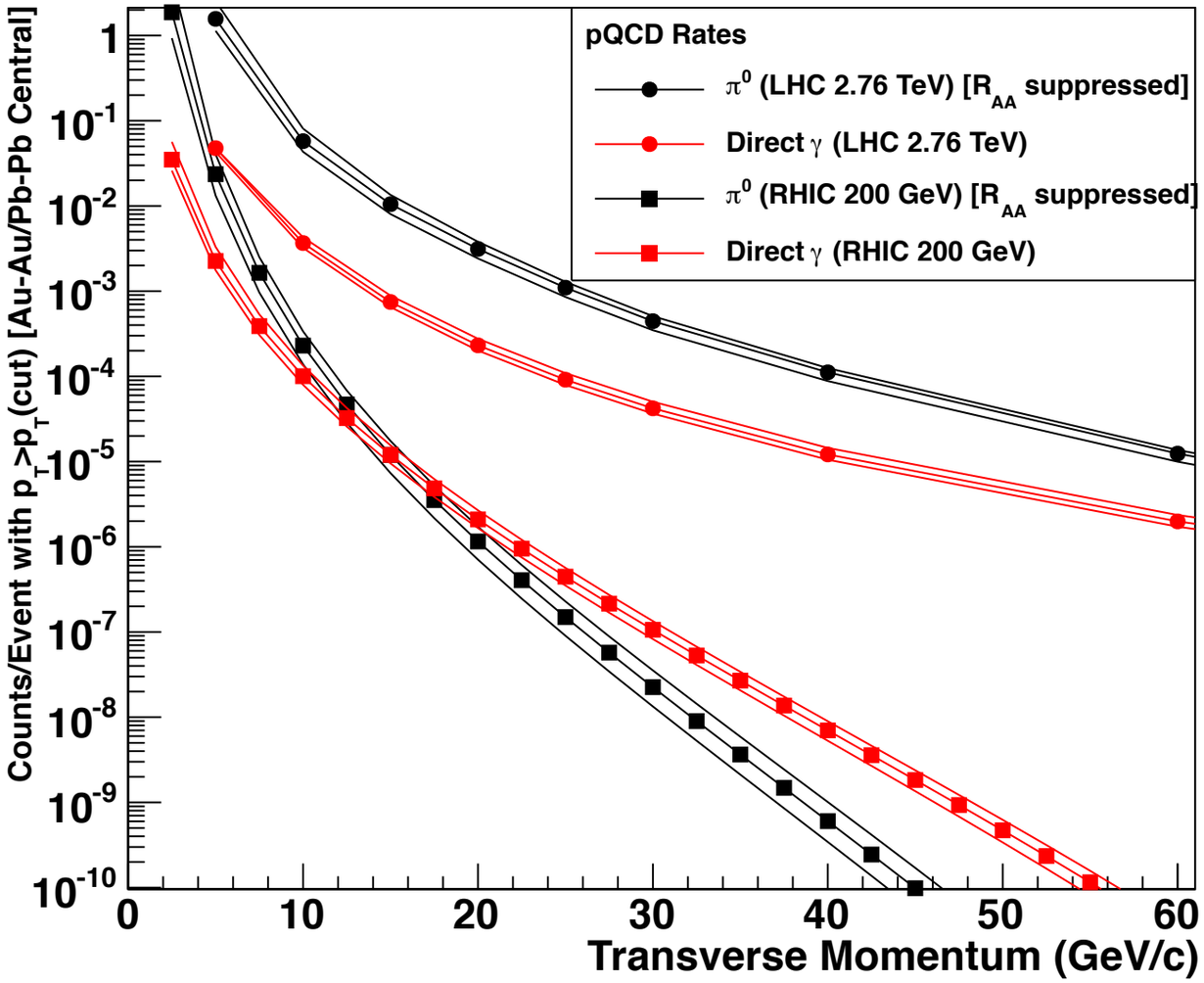
Armesto, Cunqueiro, Salgado, Xiang *JHEP*, 0802:048, 2008



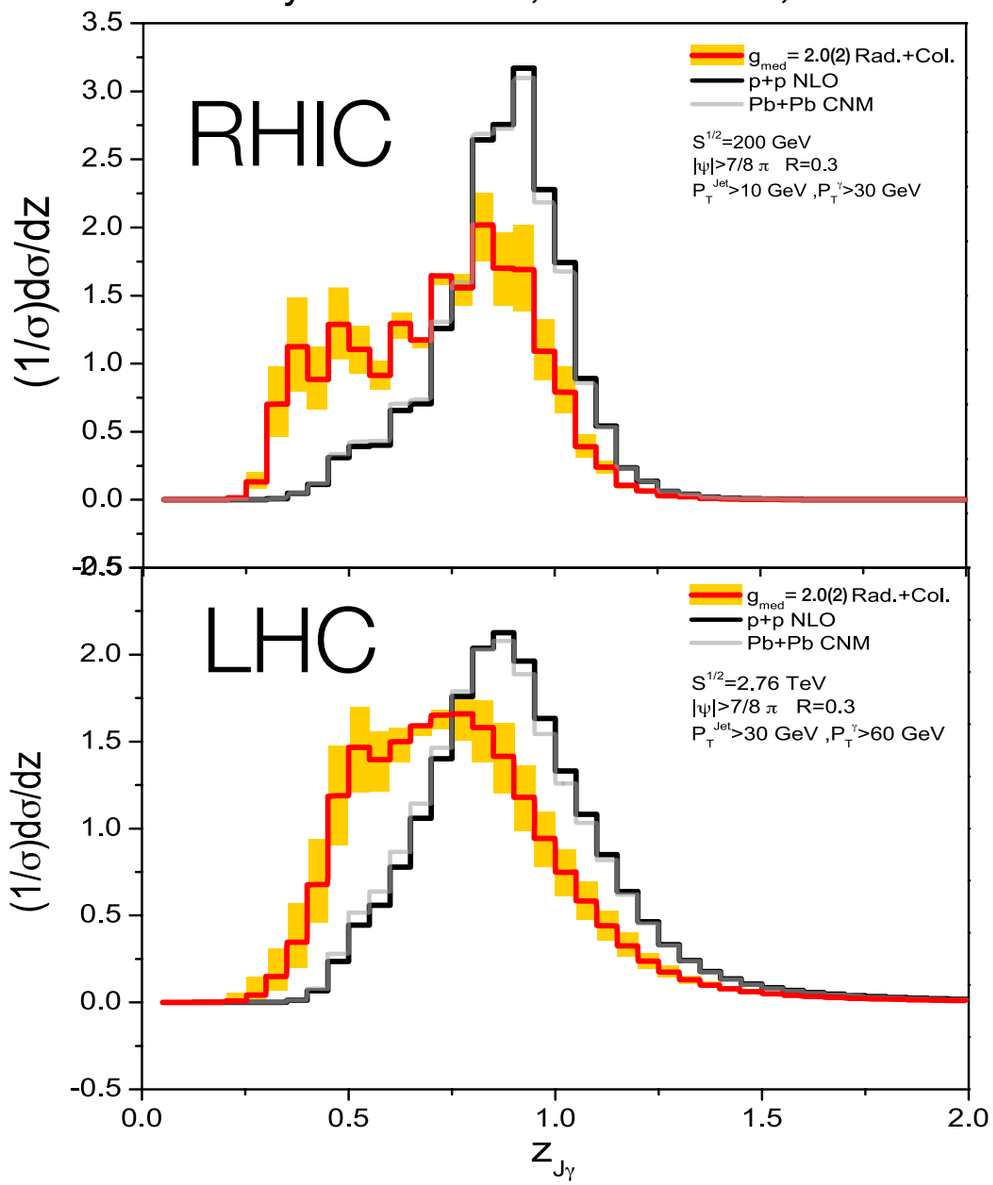


Photon-jet physics

For E_γ = 20 GeV, S/B at RHIC is **20x** higher and U.E. is **2.5x** smaller than at the LHC



Wei Dai, Ivan Vitev, Ben-Wei Zhang
Phys. Rev. Lett., 110:142001, 2013



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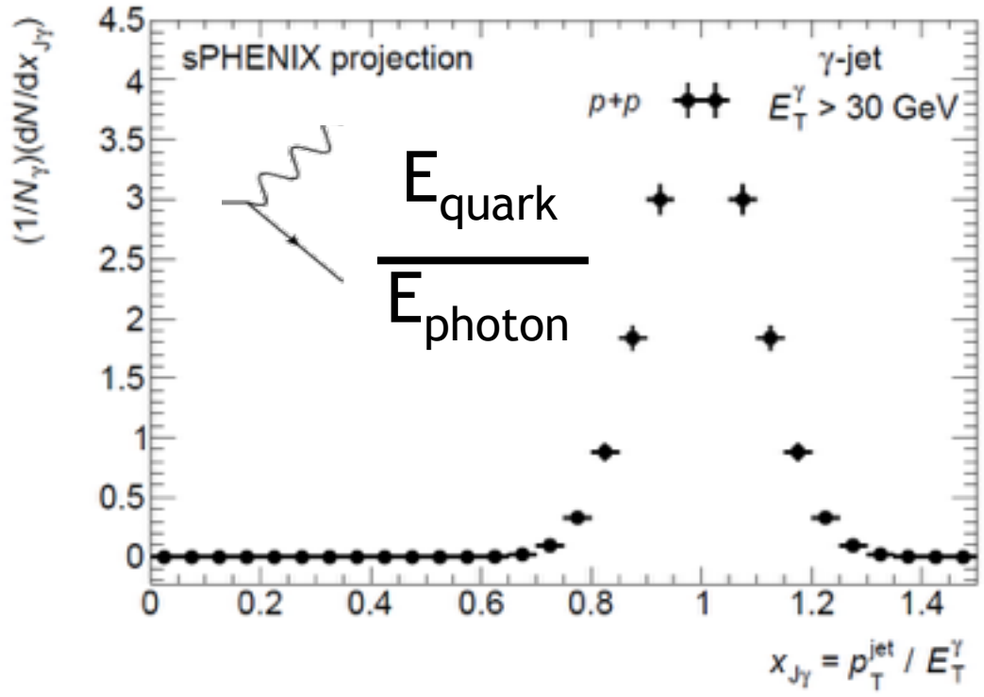

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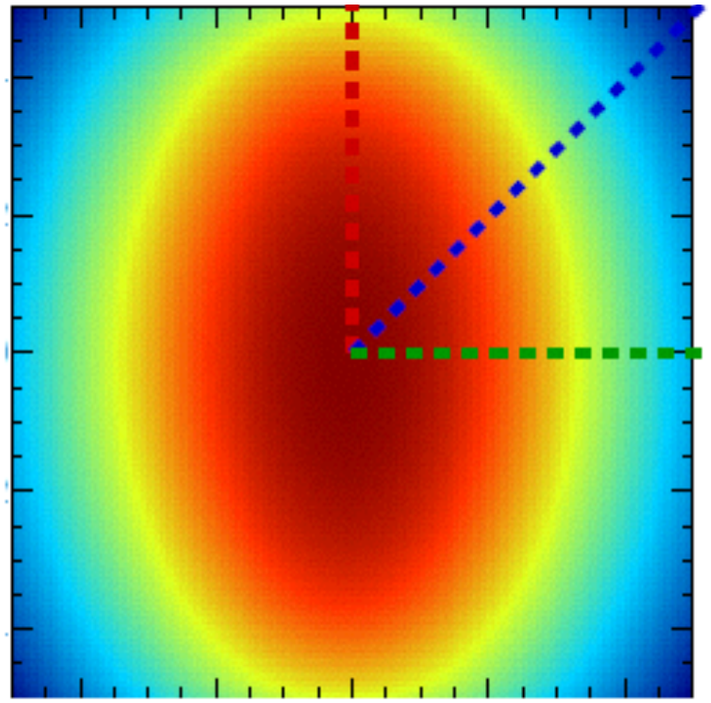

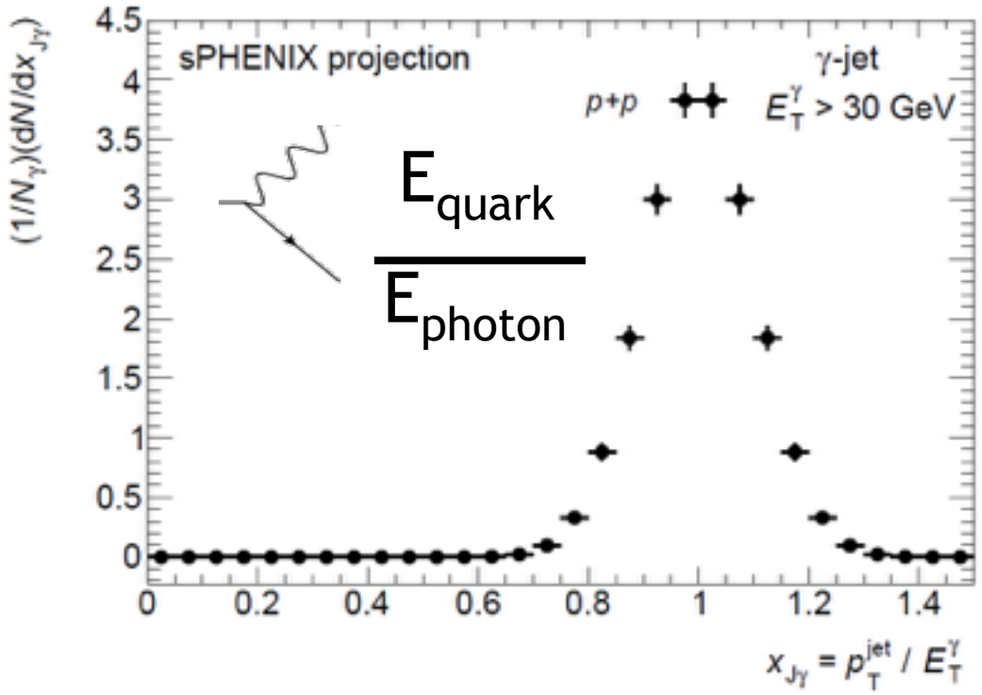

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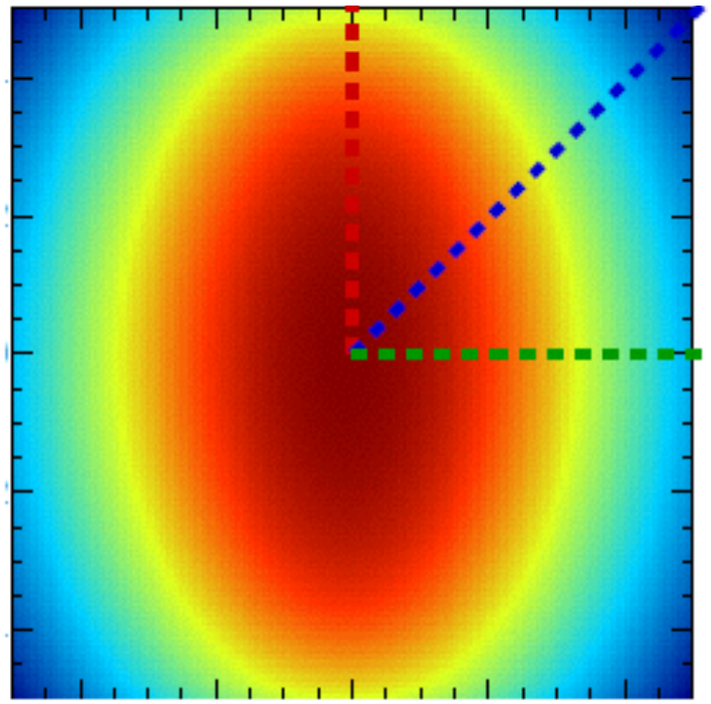

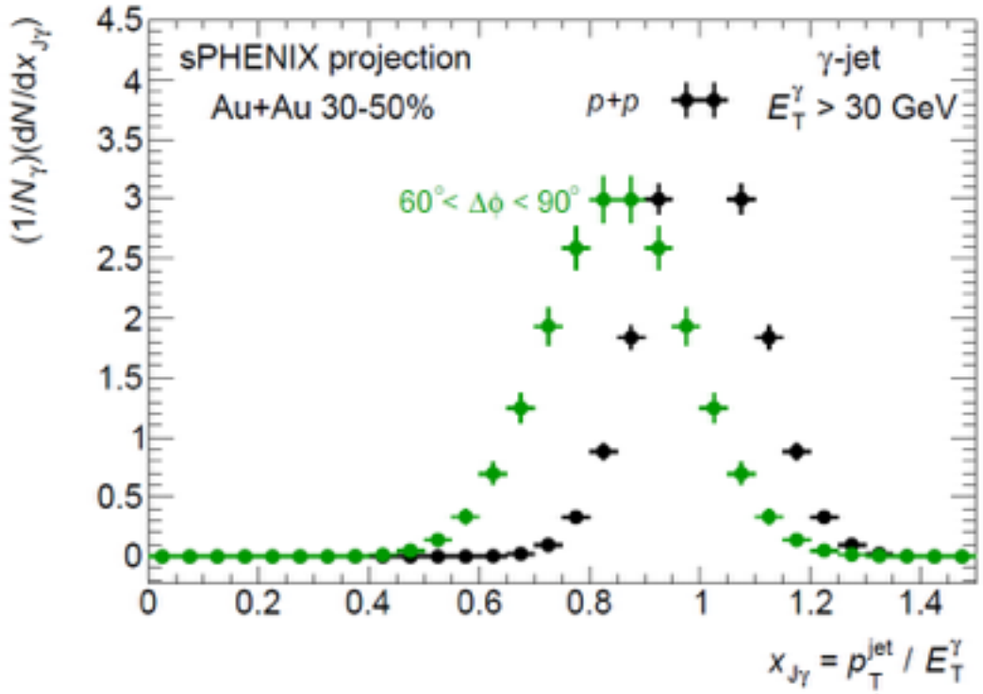

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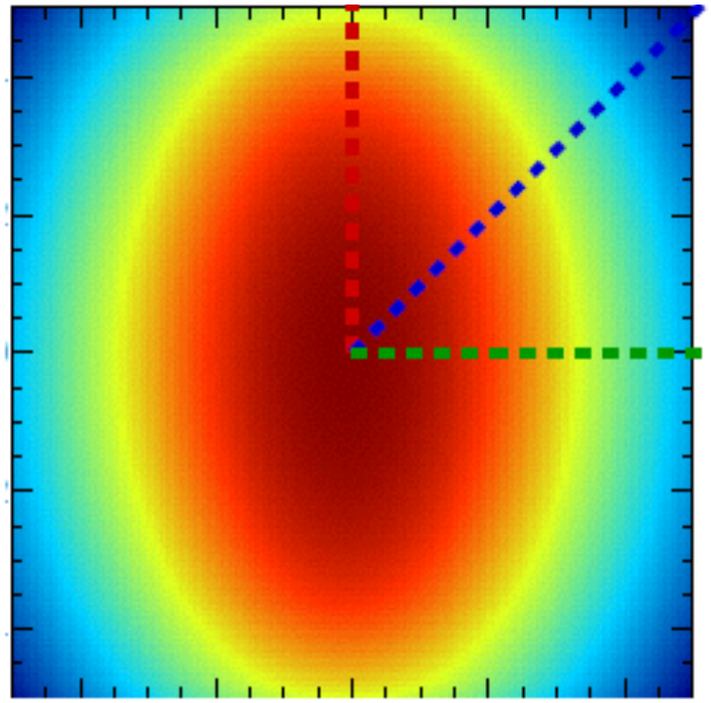

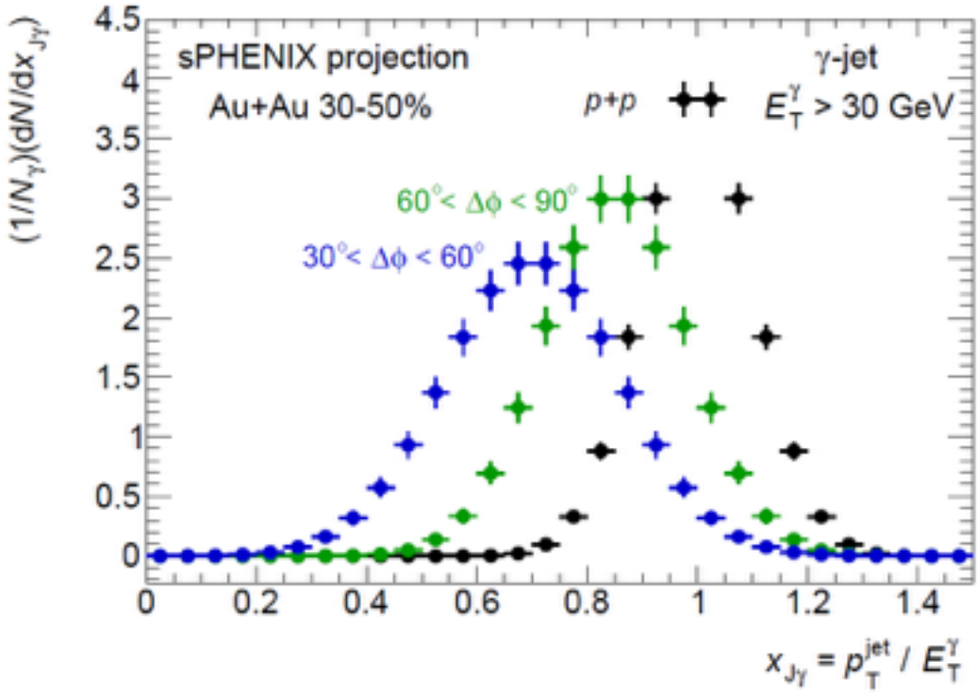

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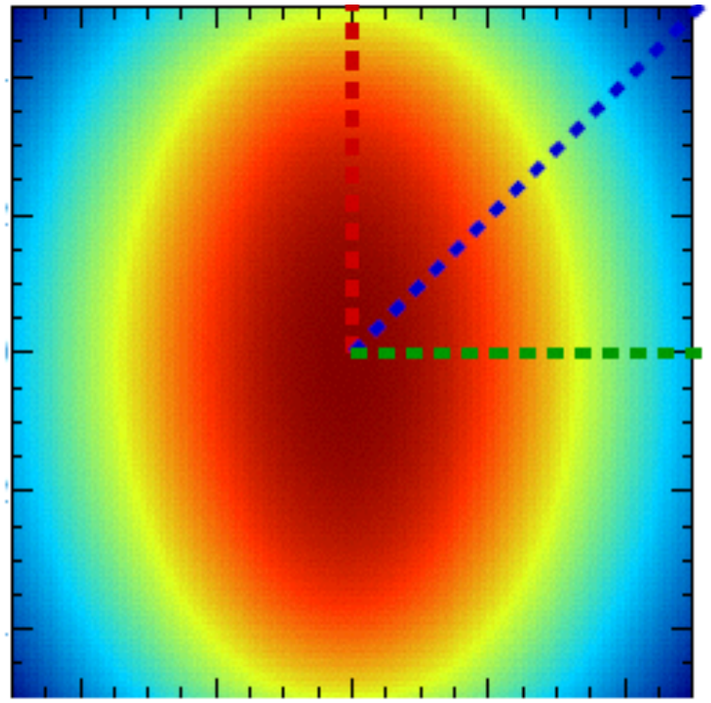

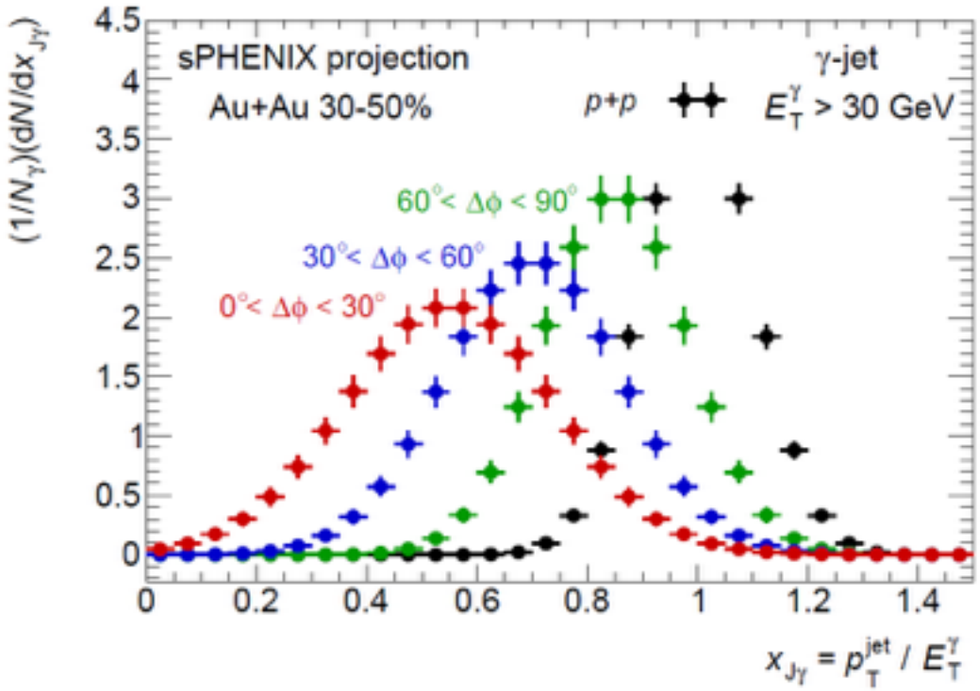

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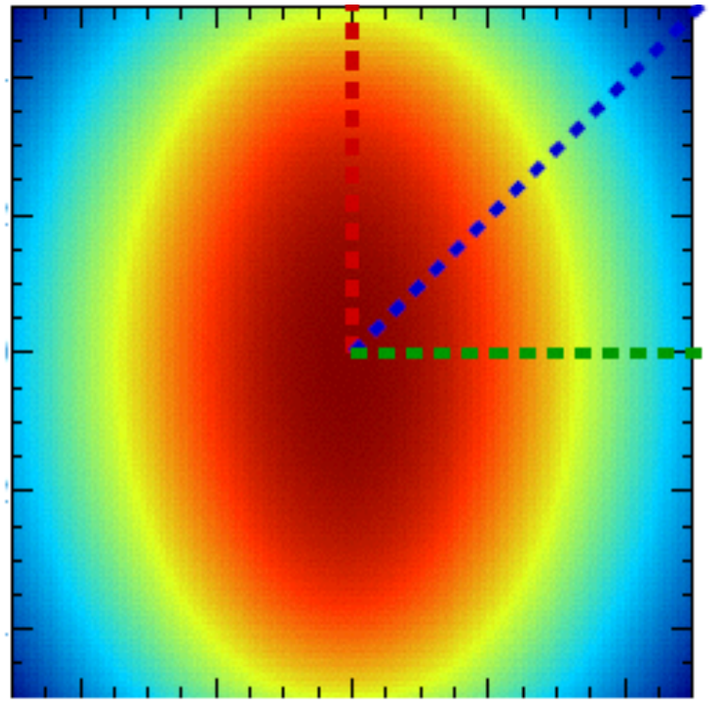
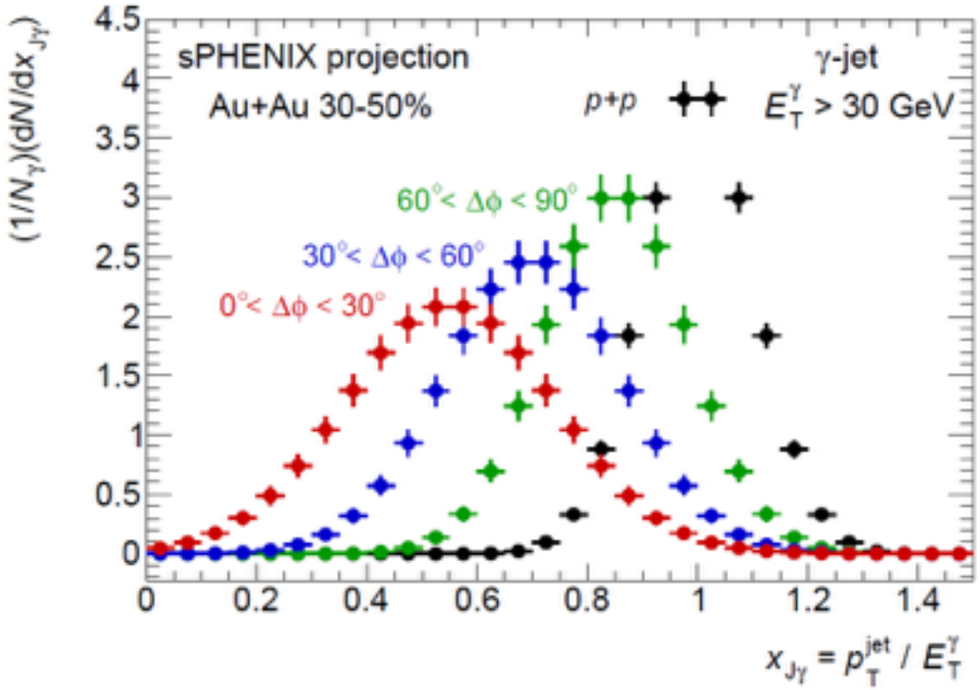
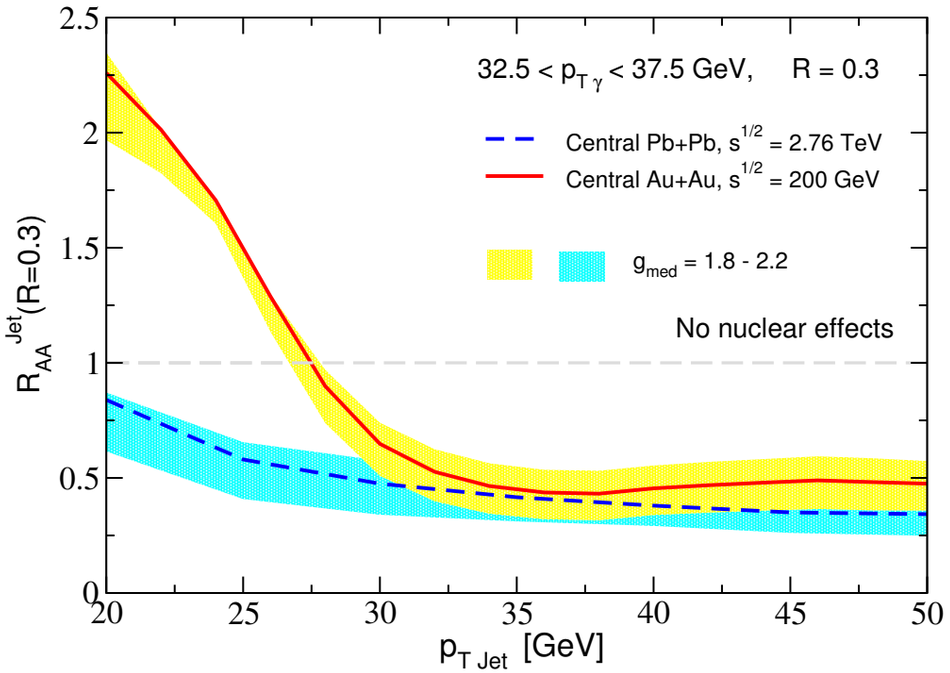
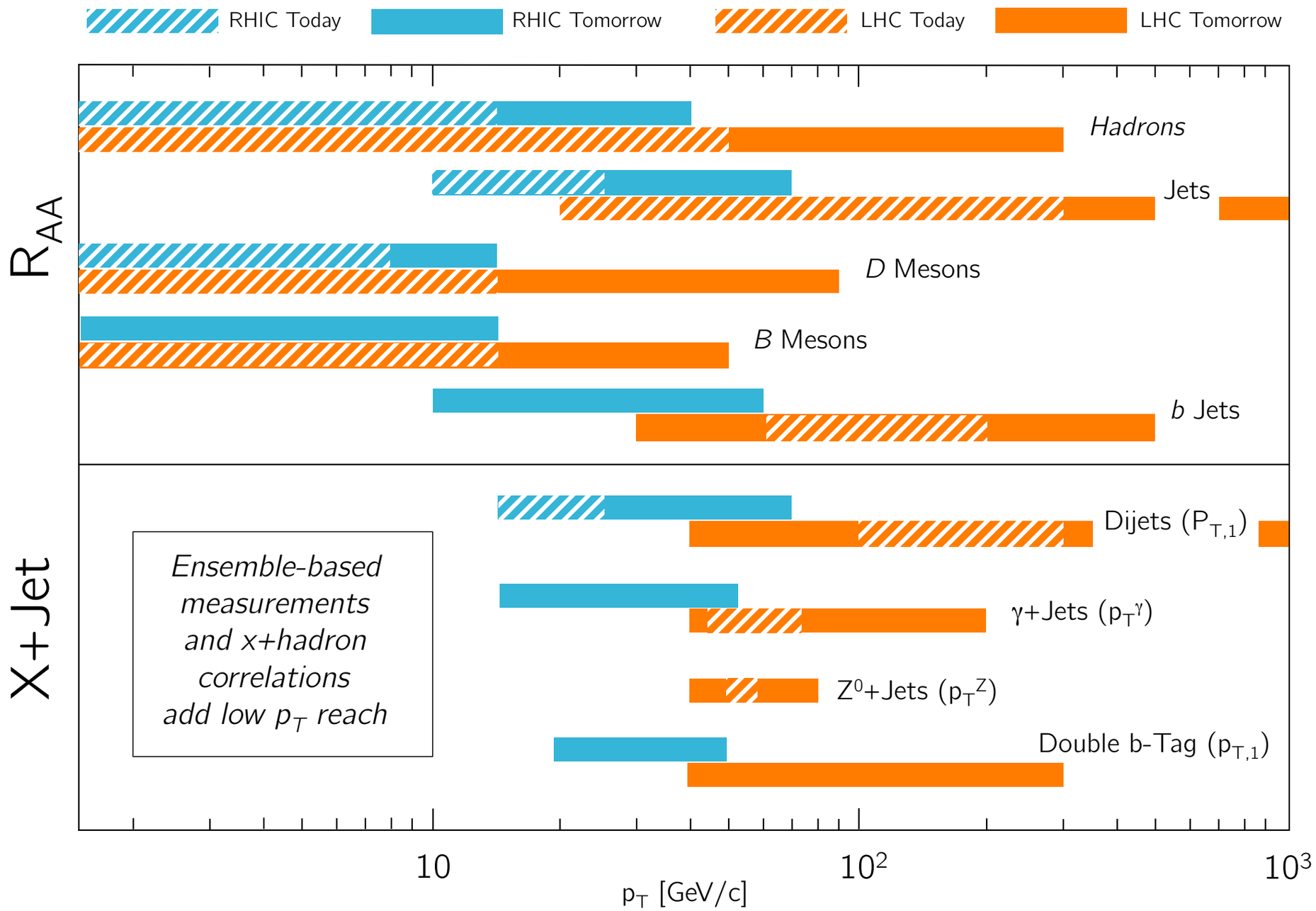




Wei Dai, Ivan Vitev, Ben-Wei Zhang
Phys. Rev. Lett., 110:142001, 2013



sPHENIX and LHC complement each other



Adapted from slides by G. Roland at the QCD Town Meeting at Temple University.

DOE review of sPHENIX science case

Review Panel Members

Peter Braun-Munzinger
Frank Chlebana
Phil Harris
Peter Jacobs
Chris Quigg
Ivan Vitev

DOE Representation

Tim Hallman
Jehanne Gillo
Jim Sowinski

April 30, 2015 at BNL

Wide range of panel expertise

- RHI experiment and theory
- QCD theory
- HEP calorimetry
- HEP jets

Very successful, very positive review
– no recommendations

http://www.bnl.gov/lajudr2015/

A Large-Acceptance Jet and Upsilon Detector for RHIC

General Workshop Registration (Deadline: June 12, 2015 12:00 AM)
Please note, this workshop is open to the public.

Begin Workshop Registration

Workshop Announcement

In April 2015, the Office of Nuclear Physics in the Department of Energy conducted a review of the science program enabled by a new detector, sPHENIX, that focuses on large acceptance, ultra-high rate measurements of fully reconstructed jets and high resolution spectroscopy of Upsilon states at RHIC. The outcome of that review was very positive and, while there are important elements of the DOE review process that remain to be completed, the Laboratory believes it is timely to organize a one-day workshop that will serve as an initial step toward the formation of a new scientific collaboration, which will further refine the science priorities; develop the formal proposal to build and operate the detector; and, if successful, exploit its unique physics capabilities.

Workshop Date
June 16, 2015

Workshop Location
Brookhaven National Laboratory
Upton, NY 11973 USA

Physics Department (Bldg 510)
Large Seminar Room

Directions and Maps
To Event | To BNL

Workshop Coordinator
Fran Capasso
Bus: 631-344-3830
Fax: 631-344-5820
Email: capasso@bnl.gov

Add to Calendar

Followup …

On behalf of the Laboratory we would like to thank all participants of last week's Workshop on "A Large-Acceptance Jet and Upsilon Detector for RHIC" for their active participation and constructive discussions about the organization of the future RHIC program. We also thank all presenters for their contributions that helped to make the meeting successful.

During the afternoon discussion it was concluded that we should move expeditiously to form a new detector collaboration to take advantage of the physics opportunities offered by a large acceptance detector built around the BaBar magnet. Although a unique core science program for the new detector has already been identified and strongly endorsed by DOE review, it is not too late to consider expanding the program to make use of the unique capabilities of RHIC, especially polarized protons and its wide energy range.

We invite all scientists and institutions who have an interest in this effort to **send email to Peter Yamin <yamin@bnl.gov> including their name, institution, and email address no later than July 16, 2015**. If there is more than one interested scientist at the same institution, we ask them to identify the person who will serve on the provisional Institutional Board (IB) for the new detector collaboration. The aim will be to constitute and convene, via videoconference, a provisional IB by the end of July.

Finally, we address the question of the Lab's policy with respect to membership of a scientist or an institution in more than one RHIC detector collaboration. BNL does not discourage participation in more than one RHIC detector. Both existing RHIC collaborations (PHENIX and STAR) have confirmed that their by-laws do not prohibit individual or institutional membership in multiple RHIC detectors, as long as the members fulfill all their duties in each collaboration. As RHIC enters a period in which detectors will focus on more specialized parts of the overall scientific program, we expect that membership of an individual or an institution in more than one detector collaboration will become more common, as it allows participation is the full scientific scope of the RHIC science program.

James Dunlop
Berndt Mueller

sPHENIX

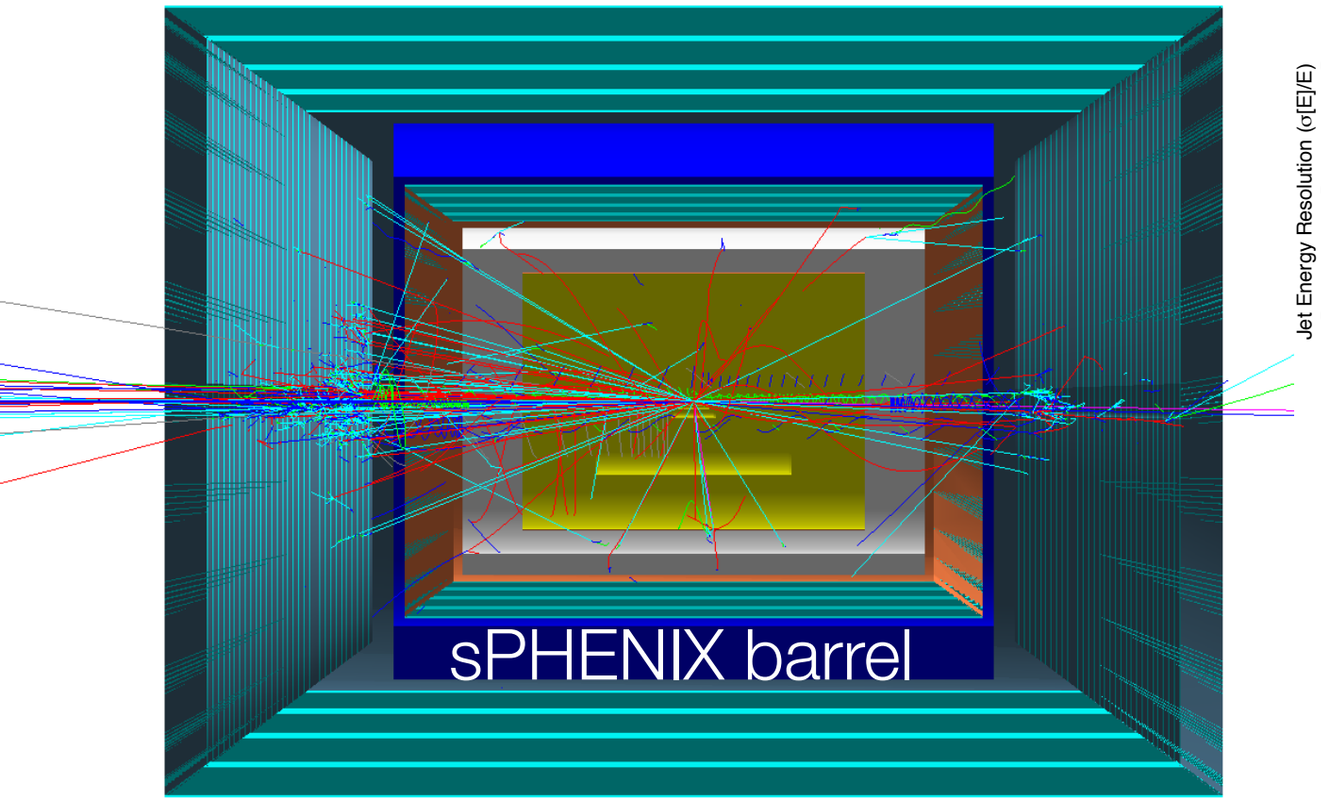
- high-rate, full calorimetry, precision tracking to record 100 billion (sample 0.1 trillion) Au+Au events and corresponding *p*+*p* and *p*+Au data sets to over-constrain problem

- very successful DOE sPHENIX science review, prominent part of BNL plan for coming decade, benefiting from many BNL engineering resources

- had to demonstrate *feasibility* of proposed measurements – not same as showing full range of possibilities or demonstrating optimality

- new scientific collaboration is being formed – 60 institutions have indicated interest and have named a representative

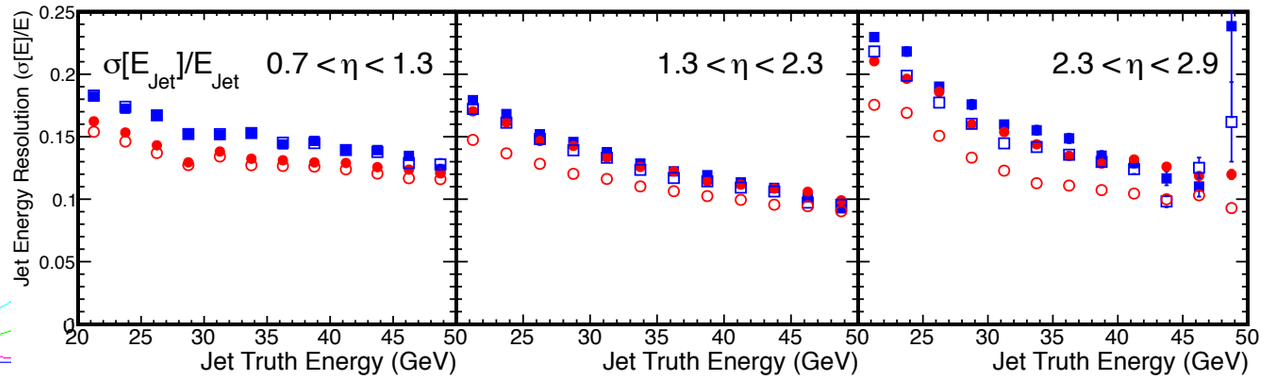
Spin physics capabilities of sPHENIX



conceivably instrument HCal encaps as "active" flux return – enabling jet and dijet measurements potentially up to $\eta = 4$

great enthusiasm in Collaboration for the physics potential, strong RIKEN interest in forward HCal

Jet energy resolution with an HCal endcap



A^{jet}_N in $p^\uparrow$+$p^\uparrow$ and $p^\uparrow$+Au with full hadronic calorimetry – analysis of Run-15 MPC-EX results will inform this

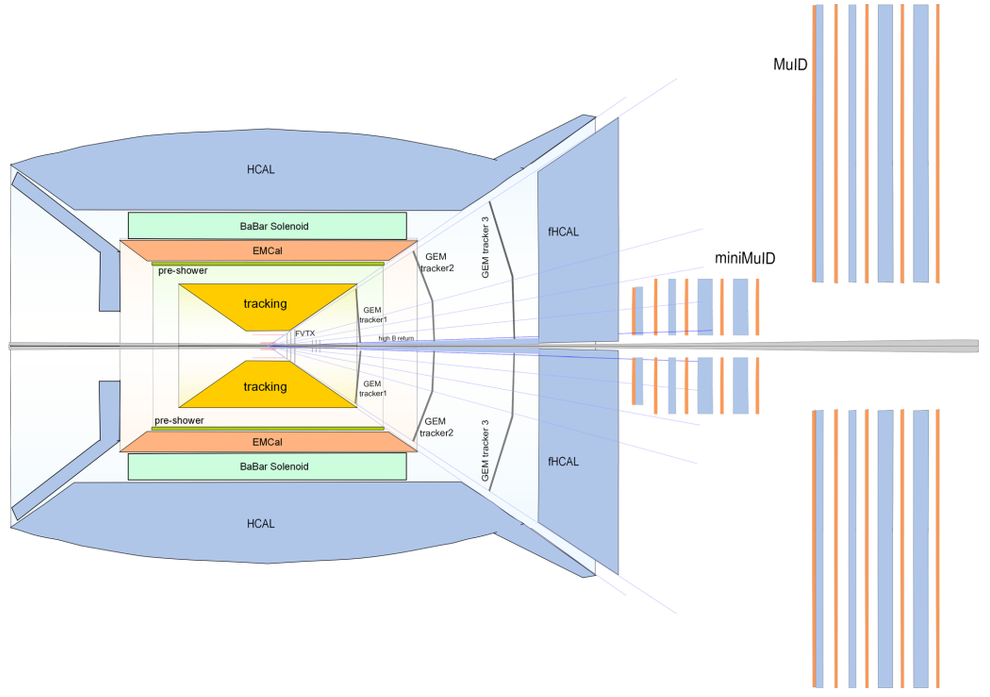
di-jets and hadron-jet and gamma-jet correlations in p+Au (CGC inspired disappearance of away-side jet)

fsPHENIX – *forward* sPHENIX adds more capability

White paper charged by ALD Berndt Mueller and shown to PAC last year
https://indico.bnl.gov/materialDisplay.py?materialId=5&confId=764

Future Opportunities in $p+p$ and $p+$A Collisions at RHIC with the Forward sPHENIX Detector

The PHENIX Collaboration
April 29, 2014



More ambitious detector concept, also more capabilities –
shaped field for high η bending power,
reconfigured FVTX for precision near vertex,
forward GEM tracking,
reuse/augment MuID

Possible step toward a day-1 EIC detector

Beyond sPHENIX

ePHENIX

A Letter of Intent from the PHENIX Collaboration

Version 1.1

October 1, 2013